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THE

ENGLISH CYCLOPÆDIA.

A New Dictionary of Universal Knowledge.

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CONDUCTED BY CHARLES KNIGHT.

ARTS AND SCIENCES.—VOLUME VII.

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THE

ENGLISH CYCLOPÆDIA.

ARTS AND SCIENCES.

RELICS (in Latin, "reliquiæ") is a term used to signify the remains, bones, or garments of departed holy men, which are honoured by the followers of the Church of Rome. During the early ages of the Christian Church, martyrs were held in veneration; and their relics were treasured up as something sacred. The anniversary of their martyrdom was celebrated by assemblies of the faithful, held round their tomb or on the places where they had perished, and chapels and sanctuaries were raised on the spot. In the 4th and 5th centuries the previous veneration for the saints became a kind of worship; miracles were said to be performed by fragments of their bones or garments, and pilgrimages were undertaken to obtain these relics. Helena, the mother of Constantine, went to Palestine, and was said to have found the identical cross on which Christ suffered. The employment of images and that of relics as accessories to church worship seem to have grown up together during that period. Towards the end of the 6th century, Pope Gregory I. displayed a great veneration for relics. There is a letter of his to the empress Constantina, who had asked him for a part of the body of St. Paul, in which he excuses himself by saying that it was not the custom of the Romans, and, in general, of the Christians of the West, to touch, much less to remove the bodies of saints; but that they put a piece of linen called "brandeum" near the holy bodies, which is afterwards withdrawn, and treasured up with due veneration in some new church, and as many miracles are wrought by it as if the bodies themselves were there: he adds that they were much surprised at the Greeks removing the bones of saints from place to place; but that in order not to disappoint the piety of the empress, he would send her some filings of the chains which St. Paul wore on his neck and hands. This letter is quoted by Baronius, Fleury, and other church historians. From that time the veneration for relics increased, but there was no longer the same scrupulosity about removing the relics. Relic worship became during the middle ages a vulgar superstition and disgraceful traffic; and the abuse has been censured by many sincere Roman Catholics. It was ordered by several synods that no relics should be exposed to view without the sanction of the local bishop. Pope Innocent III. forbade the sale of relics. The Roman Catholic Church however admits that the relics of saints have performed and may still perform miracles; and that they are a proper object of veneration.

(*Bibliothèque Sacrée, par les Pères Richard et Giraud,* articles 'Reliques' and 'Saints,' 3rd section, 'Reliques des Saints;' and also Father Honoré de Sainte Marie, *Dissertation sur les Reliques;* and the Abbé de Cordemoi, *Traité des Saintes Reliques.*)

RELIEF, RELEVIUM, a burden incident to feudal tenures, being a sum of money paid to the lord on the admittance of a fresh tenant. It is a relic of that state of things in which the succession was not strictly speaking of right, but at the will of the lord, who required the payment of such an acknowledgment for the concession. It became however so much the custom for the lords to admit the sons or near kindred (heirs, as we now say) to the inheritance of the ancestor, that a custom became established of doing so, and out of the custom grew the right. The money however which had been paid for admission in the former state of things, continued to be paid when the succession of the next heir had become what is called matter of right.

Bracton gives what is probably the true etymology of the word. "Relevia," says he, are so called, "quia hereditas quæ jacens fuit per antecessoris decessum *relevatur* in manus heredum, et propter factam relevationem."

RELIEF [ALTO-RILIEVO.]

RELIGION is a Latin word which, according to the common derivation of it (from *religare*), means a principle which acts as a *restraint* on the conduct of man. In its more general sense it is used as an abstract term to denote our ideas of the existence and character of a Divine Being, to whose power men are more or less subject. Thus we speak of *a sense of religion* and *the duties of religion*, and we call a man who regards such subjects as matters of great importance *a religious person*. But as different views have prevailed of the nature of the deity and the relation in which man stands to him, various systems of religious belief have sprung up, and each of these systems is called *a religion*. Thus we speak of the Greek, Hindu, Jewish, Christian, and Mohammedan religions. The word is also popularly used to express the attention of individuals to the doctrines and duties of the particular religion which they may have embraced. In this sense it is synonymous with *piety*.

The subjects with which religion has to do are God and man considered in the relation in which they stand to each other. It consequently includes all the philosophical questions which can throw light upon that relation; for example, those which respect the nature of the deity, the notions of infinite space and infinite duration, the existence and offices of spiritual beings, the origin and destiny of the human race and of the world they inhabit, the immateriality and immortality of the human soul; and also all the practical questions which arise out of that relation, such as the duties which men owe to God and to each other, and the consequences which God may have appointed to follow different courses of action. All impressions, notions, and belief upon these subjects, whether formed into a system or not, constitute what we call *religion*, as distinguished from *theology*, which is the science by which these ideas are reduced to a systematic form, their laws investigated, and their origin and results traced out. [THEOLOGY.]

The sources from which our notions of religion are derived are either the so-called laws of nature and the constitution of the human mind, or direct information given to us upon the subject by the deity himself, whether such information be embodied in any lasting form, or handed down from one generation to another by oral tradition. Religion derived from the two former sources is called *natural religion;* from the last, *revealed religion.* [REVELATION.]

The fundamental principle upon which all religion rests is the notion of the existence of a Being whose power over us is absolute, whose nature is perfect in excellence, to whom we owe certain duties, and from whom we have much to hope and fear. The existence of such a Being is proved by the evidences which the objects of nature present of perfect design, of fixed order, of power sufficient to accomplish everything which we can conceive that does not involve a contradiction, and which we therefore conclude to be infinite, and of benevolent provision for the wants of living creatures. Apart from all such evidence, the belief in the divine existence seems to be strongly impressed on the human mind, so strongly indeed, that it is a matter of great doubt whether even professed atheists have been really such. Lastly, this truth may be the subject of revelation; for revelation does not, as may at first sight seem, imply as a fact *previously* known the existence of the Being from whom it comes. To the first recipients of the revelation the very fact of their finding themselves possessed of the knowledge of truths beyond the range of human experience would be a sufficient proof of the existence of a superior Being, from whom they had, in whatever way, obtained such knowledge; and if, in making known the revelation to the world, these persons should display a command over the laws of nature beyond the compass of human power, or an acquaintance with future events beyond the reach of human knowledge, these miracles and prophecies would prove the existence of a superior Being, from whom they had received the power to perform the one and the foreknowledge implied in the other. Thus the revelation itself furnishes a proof of the existence of the before unknown revealer. We do not inquire whether the divine existence is really proved in either or all of these different ways, because the object of this article is to explain the nature of religion, not to establish its truth.

The belief in a God leads at once to the practice of worshipping him, on the very same principle on which all dependants honour and look up to those in whose power they are placed.

The existence of a God once proved, the next question is, In what relation do we stand to him? Are any laws laid down for our conduct? Are we responsible to him for keeping or breaking those laws? Are any rewards and punishments appointed for obedience and disobedience?

To these questions it does not appear that natural religion can give a perfectly satisfactory answer, though no one can read Bishop Butler's admirable work, 'The Analogy of Religion, Natural and Revealed, to the Constitution and Course of Nature,' without being astonished at the amount of information on these subjects which it is there shown that the contemplation of natural phenomena reveals. It seems also that a general undefined notion of responsibility is associated in nearly all human minds with the idea of divine existence, at least a sense of responsibility sufficient to excite pleasure when we do what we believe to be good, and remorse when we do what we believe to be evil. Again, the connection which we find generally existing between vice and misery on the one hand, and virtue and happiness on the other, impresses upon us the idea that there does exist such a thing as retributive justice. But at this point we encounter the great difficulty of natural religion. Though the general law according to which the affairs of the world appear to be governed is, that virtue is followed by happiness and vice by misery; and though a full knowledge of the circumstances of every case which appears an exception to that law might show us that more real happiness is enjoyed by a virtuous sufferer than by a prosperous sinner, yet it cannot be denied that daily experience furnishes us with exceptions to this law, numerous enough to throw great doubt upon its reality, if the period of human existence ends with the present life. Accordingly we find the doctrine of a future state forming a part of all religious systems, and generally connected with some notion of rewards and punishments.

Now, if there be a supreme moral governor who rules the world by fixed laws, who has appointed rewards and punishments as the recompense for obedience and disobedience, and who has constituted man so that he shall exist in a future state to receive that recompense, the question is naturally suggested whether there be any means by which the consequences of disobedience may be averted. Justice must be an attribute of the ruler of the universe, and natural religion affords us sufficient proofs of his goodness to justify us in believing that he is also willing to show mercy. The question that remains to be answered is, how his mercy can be shown without injury to his justice; and the importance of this question is enhanced by the consideration that the great majority of mankind (experience would justify us, apart from the Christian doctrine of universal depravity, in saying all mankind) need the divine forgiveness for at least some actions of their lives. It is the highest province of religion to furnish an answer to this question; and here natural religion entirely fails us, for if left to it, the utmost we could do would be to rest in the exercise of an humble faith that some provision has been made by God for the just forgiveness of our sins, though the nature of that provision be unknown to us. The matter belongs to revealed religion, and accordingly we find in nearly every religion professing to have a divine origin, and in many others, the doctrine of an atonement; that is, of a satisfaction for sin, in virtue of which the actual transgressor may be released from the consequences of his guilt.

These, then, are the elements which seem to be contained in any religion suited to the wants of man; that there exists a supreme Being who possesses absolute power over man and the material universe, and all creatures therein, and who is to be worshipped by all his rational creatures; that he has laid down laws for our conduct, by our obedience or disobedience to which we subject ourselves to a recompense of reward or punishment, which recompense is awarded partially in the present life, but more completely in a future state, in which we are so constituted as to exist after death; that a provision has been made on behalf of those who feel that their conduct has subjected them to the divine displeasure, by availing themselves of which they may escape the consequences of their guilt without detriment to the equity of the divine government; and lastly, that there are certain practical rules of conduct by which the intercourse of men with each other ought to be governed, and by an attention to which the stability of the social system may to a great extent be ensured. And all these elements of religion are susceptible of proof, either from nature, or from human experience, or from revelation.

RELIQUARY, a case or repository for relics. The term is usually confined to the smaller relic-cases, those of large dimensions, whether fixed or moveable, being more commonly designated *shrines*. When the veneration of relics had become universal in the mediæval church, the practice of enclosing the relic in its own special case, so as to preserve it alike from danger of loss and from contact with less sacred objects, was generally adopted; and these cases, often gifts to the churches, were usually of the finest workmanship of the period, and sometimes of very costly materials. Reliquaries are among the most prized remains of mediæval art-workmanship now preserved in the ecclesiastical treasuries of the continent and in public museums. They vary of course widely in pecuniary and artistic value, and also in size and form. Those of earliest date, Byzantine in character, are frequently of copper almost wholly enamelled; and a common form, when not a mere casket or coffin, is that of a chapel or basilica, having on the sides and ends figures of Christ and the apostles, or the legend of the saint whose relics they enclosed. Later, the church form is more developed, the sides and gable-ends having, especially in French and German examples, columns, arches, crockets, pinnacles, and even towers. Those of the 13th and 14th centuries are often exquisite specimens of the art of the period. They are commonly of metal—latten, silver-gilt, or gold—with figures in relief, and enamels introduced with great taste and admirably executed. Some are of wood or ivory, beautifully carved. Sometimes they assume the form of the relic itself—as a head, heart, hand, or foot, where they were made to contain a portion of one of those members. The large reliquaries, or *shrines*, were of stone or bronze, and, where regarded as of special sanctity, were overlaid with the accumulated offerings of devotees. Thus the shrine of the Three Kings at Cologne was ornamented with jewels said to be of the value of nearly a quarter of a million. The shrine of Thomas à Becket, at Canterbury, was of almost inconceivable value. Those were, however, the real or supposed tombs of the saints, and though sometimes spoken of as reliquaries, are, as we said, more properly called shrines. Of reliquaries proper some few examples remain in our churches, as at Brixworth, near Northampton; Yaxley, near Peterborough, &c. Several good examples of enamel, metal, and carved ivory reliquaries are in the South Kensington Museum.

REMAINDER. An estate in remainder is defined by Coke to be "a remnant of an estate in lands or tenements, expectant on a particular estate, created together with the same at one time." According to this definition, it must be an estate in lands or tenements, including incorporeal hereditaments, as rents and tithes; and it is an estate which at the time of its creation is not an estate in possession, but an estate the enjoyment of which is deferred. The estate in remainder may exist in lands or hereditaments held for an estate of inheritance or for life. It must be created at the same time with the preceding estate, and by the same instrument; but a will and a codicil are for this purpose the same instrument. A remainder may be limited by appointment, which is an execution of a power created by the instrument that creates the particular estate; for the instrument of appointment is legally considered as a part of the original instrument. A remainder may also be created either by deed or by will; and either according to the rules of the common law, or by the operation of the Statute of Uses, which is now the more usual means.

If a man seised in fee simple grants lands to A for years or for life, and then to B and his heirs, B has the remainder in fee, which is a present interest or estate, and he has consequently a present right to the enjoyment of the lands upon the determination of A's estate; or, in other words, he has a vested estate, which is called a vested remainder. A reversion differs from a remainder in several respects. He who grants an estate or estates out of his own estate, retains as his reversion whatever he does not grant; and upon the determination of the estate or estates which he has granted, the land reverts to him. There may be several remainders and a reversion expectant on them. If A, tenant in fee simple, limits his estate to B for years, with remainder to C for life, with remainder to D in tail, this limitation does not exhaust the estate in fee simple. By the limitation B becomes tenant in possession for years, C has a vested remainder for life, D a vested remainder in tail, and A has the reversion in fee. If the limitation by A exhaust the whole estate, as it would have done in the preceding instance if the limitation had been to C and his heirs, A has no estate left. It is a necessary consequence that if a man grants all his estate, he can grant nothing more; and therefore the grant of any estate after an estate in fee simple is void as a remainder. Indeed the word remainder implies that what is granted as such is either a part or the whole of something which still remains of the original estate.

The estate which precedes the estate in remainder or in reversion is called the *particular* estate, being a particula or portion of all the estate which is limited; and the particular estate may be any estate except an estate at will, and an estate in fee simple. It must therefore be either an estate for years, or for life, or in tail.

Estates for years may be granted to commence at a future time; but by the rules of the common law, no estate of freehold can be created to commence at a future time. If therefore such an estate of freehold is granted, there must be created at the same time an estate for years, which shall continue till the time fixed for the enjoyment of the estate of freehold.

A remainder cannot be granted so as not to take effect immediately on the determination of the particular estate. If there is any interval left between the particular estate and the remainder in their creation, the remainder is absolutely void. A grant of an estate to A, and one day after the determination thereof to B, is a void remainder.

Estates in remainder are either vested or contingent. The remainder may vest at the time of the limitation, or it may vest afterwards: in either case the remainder-man acquires an estate in the land, to the enjoyment of which he is entitled upon the determination of the preceding estate. But it may happen that a vested remainder may never become an estate in possession.

A vested remainder is an estate which, by the terms of the original limitation or conveyance, is limited or conveyed unconditionally. If a remainder is not vested, it is contingent.

A contingent remainder is defined by Fearne to be "a remainder limited so as to depend on an event or condition which may never happen or be performed, or which may not happen or be performed till after the determination of the preceding estate." Accordingly it is the limitation of the remainder which is conditional, and there is no remainder limited or given until the condition happens or is performed. The uncertainty of the remainder becoming an estate in possession is no part of the notion of a contingent remainder; for this kind of uncertainty may exist, as already observed, in the case of vested remainders.

Fearne has made four classes of contingent remainders, to some one of which he considers that all kinds of contingent remainders may be reduced, but he adds that "several cases which fall literally under one or other of the two last of those four descriptions, are nevertheless ranked among vested estates."

The first class is, "where the remainder depends entirely on a contingent determination of the preceding estate itself;" or, as it may be explained, where a remainder is limited to take effect only on the happening of a specified contingent event which is to determine the preceding estate, and is not to take effect if the preceding estate determines in any other way. An example usually given is the following: A makes a feoffment to the use of B till C returns from Rome, and after C's return, then to D in fee. In this case B has an estate which will determine either upon C's return from Rome or by his own death; but the remainder is limited to D only upon the happening of a specified event which may never happen; and if B's estate determine by his death, or by forfeiture, which is possible, no estate is limited to D. There is then no limitation to D, except conditionally, and his estate is therefore contingent.

The second class is, "where some uncertain event, unconnected with and collateral to the determination of the preceding estate, is by the nature of the limitation to precede the remainder." This class is easily distinguished from the first, by the circumstance that the uncertain event upon which the remainder is limited, is entirely independent of the manner in which the preceding estate may or must determine. The following is an example: If a grant is made to A for life, remainder to B for life, and if B die before A, remainder to C for life, the uncertain event of B's dying before A is quite independent of the determination of A's estate, but the limitation of C's estate depends on this uncertain event happening.

In both these classes of remainders, the event on which the remainder is to take effect is absolutely uncertain; in the two following classes, the events on which the remainders are limited are events which certainly must happen, and the contingency arises from the uncertainty of the time when they will happen.

The third class is, "where a remainder is limited to take effect upon an event, which, though it certainly must happen some time or other, yet may not happen till after the determination of the particular estate." The following is an example: A grant is made to J. S. for life, and after the death of J. D. the lands to remain to another in fee. Though it is certain that J. D. must die, this event, upon which the limitation in fee is to take effect, may not happen till after the determination of the life estate of J. S.

The fourth class is, "where a remainder is limited to a person not ascertained, or not in being at the time when such limitation is made." The following is an example: A grant is made to A for life, remainder to the right heirs of J. S. Now as J. S. can have no heir till he is dead, and as he may not die till after the determination of the particular estate, such remainder is contingent. If an estate is limited to two persons for life, with remainder in fee to the survivor, the remainder is contingent, because it is uncertain which will be the survivor.

The numerous exceptions to the fourth class of contingent remainders are comprehended in what is called the Rule in Shelley's case, of which a complete exposition is given in Fearne's 'Essay on Contingent Remainders;' and in Preston's 'Treatise on Estates' (vol. i.). The nature of this rule may be generally stated as follows:—If lands are limited, either by deed or will, to a man for life, and after his death to his heirs or the heirs of his body, the limitation to the heirs would appear to be a contingent remainder according to the definition of the fourth class of contingent remainders, for the heirs are persons who cannot be ascertained till the death of the person to whom the estate for life is given. But it is an old rule of law that the estate so limited to the heirs or the heirs of the body takes immediate effect as an estate in the ancestor, and therefore, in the former case, A takes an estate of freehold with a vested remainder in fee. His life estate is consequently merged in his remainder in fee, and he becomes tenant in fee simple in possession. If an estate for life, or an estate tail, is interposed between the estate for life to the ancestor and the remainder to his heirs or the heirs of his body, still this remainder is vested in the ancestor, just in the same way as if it were limited to him and his heirs, or to him and the heirs of his body. Thus when A takes an estate for life, remainder to B for life, remainder to C in tail, remainder to the right heirs of A, this ultimate remainder is a vested remainder in fee in A, and, after his death and the determination of the intermediate estates, his heir will take by descent. But cases within this rule are not so properly exceptions, as cases which by the operation of the rule are excluded from the fourth class of contingent remainders.

There is another exception to the fourth class, which is allowed in devises, where it can be clearly inferred from the particular expressions in the will, that a limitation to the heir special of a person then living is intended as a designation of a particular person. In such case the remainder will vest; for the conclusion is, not that the testator intended to limit the estate by way of contingent remainder to such person as should be ascertained to be heir by the death of his ancestor, but that he intended by the word "heir," accompanied with the other expressions in the will, to designate a particular person.

A contingent remainder may intervene between the particular estate and other limitations over, and yet the subsequent limitations may be vested, if made to a person *in esse,* provided the contingent limitation is not in fee simple. The contingent remainder itself may also vest, and then become an estate interposed between the particular estate and the subsequent vested limitations, if the contingency happens during the existence of the particular estate. If in the same conveyance an estate is limited to A for life, followed by a contingent remainder and a subsequent limitation to A and his heirs, or A and the heirs of his body, this last limitation, though executed under the rule in Shelley's case, is still so executed as to allow the contingent remainder to interpose as a vested estate when the contingency happens. A subsequent contingent limitation may vest before a preceding one, but it follows from what has been said that the preceding one is still capable of vesting.

Lands may be so limited as to be subject to a general power of appointment. In such cases, the general power of appointment will not prevent the estates limited in default of appointment from vesting; though the due exercise of the power will divest them.

A contingent remainder may be limited generally upon any event, except in such cases as the following:—the contingent event being illegal; the remote possibility of the contingent event; and the condition enuring to defeat the preceding estate. These subjects are fully discussed by Fearne (c. 2).

It will be collected from what has been said that a contingent remainder of freehold must be preceded by a vested estate of freehold; for if there is no precedent vested estate of freehold, and the freehold remainder is contingent, the freehold either remains in the grantor, and therefore is not transferred to any one else, or it is transferred in some remainder which is limited after the contingent remainder, and which, being therefore vested in possession, precludes all possibility of the vesting of the contingent estate, which by the terms of the limitation must precede it. This rule as to the necessity of a vested freehold estate to support a contingent remainder, applies both to limitations of uses and of estates limited at common law.

It will also appear from the definitions of contingent remainders that they must vest, that is, the conditions on which they are limited must be fulfilled, during the continuance of the particular estate or immediately on its determination. One of the cases in which such remainders were formerly liable to fail under the fourth class of contingent remainders, was in the case of such limitations as to A for life, and to his first and other sons in tail. Originally a posthumous son could not take, but such child is now for this and several other purposes considered as a person *in esse* during the period of pregnancy. When a contingent remainder is limited to several in a conveyance to uses or by a devise, such remainder will vest in the first person in whom it can vest, but it will divest in due proportions in favour of other persons who are included in the limitations, and who become capable of taking before the determination of the particular estate; and such persons may take as joint tenants, though their estates vest at different times.

Formerly, any determination of the particular estate before a legal remainder vested, destroyed the contingent remainder. The contingent remainder might fail not only through the contingency not happening till after the expiration of the particular estate, but through its destruction by the surrender of the tenant for life, or by the forfeiture of his estate during the existence of the contingency. The intermediate contingent remainder was also destroyed if the particular estate and the next vested estate of freehold became united by the conveyance or act of the parties, so that the particular estate was merged. Now, however, it has been enacted by the statute 8 & 9 Vict. c. 106, that contingent remainders shall be capable of taking effect, notwithstanding the determination by *forfeiture, surrender,* or *merger* of any preceding estate of freehold.

A contingent remainder of an estate of inheritance is descendible to the heirs of an ascertained person to whom it is limited, if such person should die before the contingency happens, and it will vest if the same should happen during the continuance of the particular estate. Contingent remainders were once not considered devisable, but it was afterwards determined that they were devisable whenever they were descendible to the heirs of the persons to whom they were limited; and under the statute 1 Vict. c. 26, they are devisable in common with all contingent, executory, or other future interests in any real or personal estate.

Though a fee cannot be limited after a fee as a remainder, two or more contingent fees may be limited in the alternative, so that one only shall take effect.

Interests in chattels real and personal are susceptible of limitations over after the limitation of some partial interest in them; but from the nature of those interests they are incapable of such extensive modifications as freehold interests in land, and they cannot be operated upon by the Statute of Uses. Originally a bequest of a term of years to a man for his life was an absolute gift of the whole term, and the donee might dispose of the whole interest as he pleased; but at present a bequest of such term to A for life, and after his death to B, is a bequest of the whole term to A, subject to an executory bequest to B, to take effect if A dies before the expiration of the term. It is not a particular estate to A for life and a remainder to B. Any disposition of a chattel, which in the case of lands would make an estate tail, gives the whole interest. Thus if the second bequest of the term of years were to B and the heirs of his body, B would take the whole interest.

An executory devise is such a limitation of a future estate in lands, and an executory bequest is such a limitation of a future interest in chattels, as are allowed in the case of a will, though not in conveyances at common law. Accordingly a fee may be limited after a fee in a will or by way of use upon contingencies which may happen within certain limits of time; and such limitations take effect as executory devises or springing or shifting uses. But when future estates are so limited by devise as to be comprehended within the rules which apply to contingent remainders, they will be considered as such, and not as executory devises.

The subject of contingent remainders is fully discussed in the elaborate Essay of Fearne on 'Contingent Remainders and Executory Devises;' see also Hayes, 'On Conveyancing,' Appendix.

REMEMBRANCERS (*rememoratores*), formerly called clerks of the remembrance (37 Edw. III. c. 4), are officers of whom, until recently, there were three in the exchequer, called respectively the king's remembrancer, the lord treasurer's remembrancer, and the remembrancer of first fruits; their duty being to put the lord treasurer and the barons of the exchequer, who are the judges of that court, in remembrance of such things as are to be called on and done for the king's benefit.

I. The office of the queen's remembrancer has relation to the proceedings of the court of exchequer in the exercise of its original jurisdiction as a court of revenue, and of its incidental jurisdiction as a court of equity, founded upon the fiction that the party seeking for relief upon matters of equity is a debtor and an accountant to the crown, who by reason of the withholding of that to which he is equitably entitled, is the less able (*quo minus sufficiens existit*) to pay his debts to the crown. On the revenue side, the queen's remembrancer enters all the recognizances taken before the barons for any of the queen's debts, for appearances, &c., and he takes all bonds for such debts, and for the due execution of offices, and makes out process for breach of them; he also writes process against the collectors of customs, excise, and other public payments, for their accounts. Informations for intrusion into the queen's lands, and information for debts due to the crown, and on penal statutes, are entered and sued in his office; and he makes the bills of composition on penal laws. Indentures and other evidences which relate to the passing of any lands to or from the crown are delivered into his office; and commissions of nisi prius, by her majesty's warrant, on trial of any matters within his office, commissions to find debts due to the crown, and writs of extent awarded in pursuance of 33 Hen. VIII. c. 39, are issued and prosecuted in this office; also general process for the recovery of arrears of taxes and other debts due to the crown, which issue twice a year. All differences as to irregularities in proceedings are determined by the queen's remembrancer, with power to give costs against the party in fault, but subject to an appeal to the court. (5 Rich. II. st. 1, cc. 15, 16; 13 & 14 Car. II. c. 21.) He is bound by a rule of court, 3 Jac. II., to attend the court during its sittings, to answer inquiries respecting the course of proceedings, and to enter the rules and orders of the court of exchequer relating to its fiscal or its equitable jurisdiction, and he executes the duties formerly performed by the lord treasurer's remembrancer, now abolished by 3 & 4 Will. IV. c. 99. This office is now held by one of the masters. (22 & 23 Vict. c. 21.)

II. The lord treasurer's remembrancer's office was the office principally concerned in matters relating to the landed and casual revenue of the crown. When the king's title was found by an inquest of office, it became the duty of the officer with whom the writ and inquisition remained, to send a transcript into the office, in order to being put in charge for the service of the crown; he issued process for debts to the king, and against sheriffs, escheators, &c., and others who did not account. He took the accounts of all sheriffs, and made the record, whereby it appeared whether sheriffs and other accountants paid their proffers, that is, the balance appearing upon their accounts, due at Easter and Michaelmas, and he made another record showing whether sheriffs and other accountants kept their days prefixed. There were also brought into his office all the accounts of customers, comptrollers, and accountants, which were to be entered on record.

All estreats of fines, issues, and amerciaments, set or imposed in any of the courts at Westminster, or at the assizes or sessions, were certified into his office, and by him delivered to the clerk of the estreats, to make out process on them; and he might issue process for discovery of tenures and all revenue due to the crown by reason thereof, &c. As soon as the estreats came into this office, the parties interested might appear and deny the king's right, upon which the pleadings between the crown and the claimant were carried on in this office according to the course of the common law; and the right was either determined by the court upon demurrer or by verdict of a jury. The pleadings and judgments were entered on rolls called the 'Memoranda' of each year. Those of the reign of Edw. I. were published by Serjeant Maynard, in the first volume of his edition of the Year-Books.

Parties may apply in a summary manner for the indulgence of the court of exchequer, which is empowered by privy seal, at the commencement of every reign, to compound or discharge any fines, issues, amerciaments, or recognizances, according to the circumstances of each case; and until the statute of 3 & 4 Will. IV. c. 99, such applications passed through this office. By that statute, the office of the lord treasurer's remembrancer was, with the offices connected therewith, abolished. Part of the duties of this office had been previously transferred to other offices, part ceased by the Act, and the remainder are performed by the queen's remembrancer.

III. The remembrancer of the first fruits office receives the bishops' returns of institutions, takes all compositions and bonds for payment of first fruits and tenths, and makes process against all such persons as do not pay the same.

IV. Remembrancer of the City of London. The duties of this officer are those of agent for the corporation in parliament, and at the council and treasury boards. He gives a daily attendance at the houses of parliament during every session, to examine all bills and proceedings of the houses of lords and commons, and to report on such as may be likely to affect the interest or privileges of the city. For this purpose, the officers of both houses of parliament give him facilities of admission and attendance; and, for the purpose of identification by them, he sometimes wears a medal with the arms of the city. His duty is further to take the necessary steps to procure the presentation of all addresses and resolutions of the corporation to the sovereign and all the branches of the royal family: to make copies of the addresses and deliver the same, and to attend the sheriffs, when the appointment is made to receive the address or resolution, and the corporation, when the same is presented: to engross all petitions of the corporation to be presented to either house of parliament: to make and deliver copies, and to attend when the petitions are presented. If the petition be to the house of lords, the remembrancer, with the sheriffs, waits on some peer of parliament, and requests him to present it. He has to give the city members and the sheriffs notice when petitions are to be presented to the house of commons: to make applications for obtaining, and, when received, to distribute, the city imposts for duties on wine, an allowance made by the lords of the treasury, the origin of which is not known. The earliest entry of its being made is about the year 1680. The sum allowed is 100*l.* 16*s.*, which is distributed in different proportions amongst the lord mayor, aldermen, recorder, sheriffs, common serjeant, chamberlain, town-clerk, remembrancer, and sword-bearer. ('Second Report on Municipal Corporations of England and Wales,' 1837.)

REMONSTRANTS. [PELAGIUS, in BIOG. DIV.]

RENAISSANCE (Architecture). The term Renaissance indicates the period of the *Revival*, when the classical began to be re-introduced after the mediæval styles. The term is used alike in architecture, sculpture, and ornamental art: our attention in the present article will be confined to architecture.

The Renaissance had its origin in Italy, where at best Gothic architecture secured but a precarious hold. As soon as the passion for the old Roman literature sprang up, there arose also a desire for the study of classic art, to be followed before long by the attempt to imitate it. Traces of the imitation of Roman architectural forms are observable of as early a date as the middle of the 14th century. But the true Renaissance dates from the time of Brunelleschi (or the early part of the 15th century), in whose hands it assumed character and consistency. Its full development, however, belongs to the century following. [ITALIAN ARCHITECTURE.]

Although all were derived from that of Italy, each country had its peculiar Renaissance, described accordingly as French, German, English Renaissance [ELIZABETHAN ARCHITECTURE], preserving a general family likeness, but each exhibiting traits exclusively its own. The Renaissance in general is often spoken of as if it were nothing more than a direct but unskilful imitation of the antique, previously to the orders being so well understood as they were afterwards when studied through the text of Vitruvius, and reduced to a methodical system of "bookish rules," by Palladio and Vignola. But in the first place it was founded only upon the *Roman* antique, and in the next, not upon the temple style of the Romans, but their triumphal arches, baths, and other edifices. It was not either the portico, or the continuous colonnade, where columniation displays itself in all its purity, that was taken as a model, but rather such structures as the Colosseum, where several small orders—that is, small in proportion to the general mass—are introduced for little more than decoration to it. And in the Renaissance and Cinque-cento (or 1500—as we should say, 16th century) styles, entire orders are used only as embellishment, and avowedly so. Where columns are employed for actual support, as in open loggie, it is only in combination with arches springing from them, the columns performing the office of piers to the arches. A great deal of Italian Renaissance is, however, *astylar*, with either a full entablature, or a cornicione crowning and proportioned to the entire mass. This large and simple mode of treatment was greatly affected by the Florentine and Roman architects of the period of the revival, and contrasts very strikingly with the Transalpine Renaissance in France and other countries, which is characterised by multiplicity of parts, and numerous divisions and breaks. It contrasts also with the contemporary practice of the Italian architects themselves when they employed the orders, in doing which they made their compositions *microstylar*, applying a separate small order to each floor or horizontal division of a façade, above the ground floor; and they further reduced the height of the columns by giving a considerable proportion of each order to high pedestals beneath the columns.

In Transalpine Renaissance such application of the orders was greatly exaggerated, they being employed for the ground floor as well as the others, and the spaces between the columns being filled in, either entirely or nearly so, with large windows, so that the columns or pilasters between them show only as accessories to the windows themselves, and as narrow piers between them. Fenestration completely predominates, both as to the quantity of surface the openings occupy, and the architectural character occasioned by it. One of the earliest importations of the Renaissance into this country, Longleat House, Wilts, erected by John of Padua, 1567, is an instance of such mode of composition, and shows how greatly the borrowed style was transformed in its general physiognomy, even when treated faithfully with regard to details.

One deviation from Italian practice was the frequent employment of coupled columns or pilasters, which was in some cases (as at Wollaton Hall, see ELIZABETHAN ARCHITECTURE) caused by the necessity for wider piers between the windows, at the same time that the intercolumns were completely occupied by the windows, which last, it should be observed, retained their Tudor or English character, being very spacious and divided by mullions and transoms.

In much of the Italian Renaissance, especially in that for which purity and correctness were affected, the character of the detail is somewhat dry and meagre, and there is very little of ornamentation, even the entablatures to Corinthian columns consisting of only plain mouldings. Florid Renaissance, as it may for distinction's sake be called—seems, on the contrary, to have been most in favour both in France and in our country, probably in consequence of the taste for luxuriant enrichment which had been indulged during that period of Gothic architecture which the new style was beginning to replace. Besides which, it was out of Italy adopted as an exotic fashion, owing to which and to its being at first employed for palatial and sumptuous structures, it was displayed in all its luxuriance. This florid species of the style and period is marked by a profusion of enrichment and carvings in mouldings, panels, and friezes, by arabesque foliage and medallions, with which surfaces of considerable extent are oftentimes covered. The carvings consist of grotesque animals, foliage, &c., extended into scroll-work, interlaced in an entirely capricious manner, of the kind known as ARABESQUE. In Italian Renaissance the same kind of sculpture occurs, but purer in design, more graceful in style, and more refined in execution. Figures of Amorini, with medallions, on which are portraits, armorial bearings, &c., are common, especially in interiors. Even the shafts of columns are frequently damasked or broidered, if not for their entire height, for a considerable portion of it, and generally the lower ones, with foliage and other chasing; besides which they are further enriched by one or more bands embossed in similar manner. The faces both of pilasters and pedestals are also highly decorated by being panelled, and filled up with arabesque work or other sculptures. Niches, too, are frequent features in composition, and within, their heads are generally carved to resemble a shell; as are also devices, mottos, and other inscriptions. This profusion of minute ornament is eminently characteristic of the Renaissance taste in building, furniture, and decoration generally; and though it was then carried to excess, and the combinations themselves were often very uncouth, grotesque, and what is understood by the term quaint (oddly picturesque, but not beautiful), much of the ornament is, taken separately, marked by elegance as well as fancy. Some examples from Italian interiors, of characteristic design and admirably carved, may be seen in the South Kensington Museum.

French Renaissance dates from the reign of Louis XII., who employed Italian artists, and among others the architect Giocondo [GIOCONDO, in BIOG. DIV.], who erected for Cardinal d'Amboise, the minister of that monarch, the celebrated Château Gaillon. Though that edifice—at least what remained of it,—was taken down some years ago, it is known from the representations of it, and also from such fragments of it as have been preserved by being reconstructed at the Ecole des Beaux-Arts, Paris, to have been an exceedingly sumptuous pile. The buildings towards the court were almost entirely incrusted over with panelled pilasters, arabesques, medallions, and other sculpture. The Château de Blois, the birth-place of Louis XII., and restored and decorated by him, was another distinguished work of that period, and probably one of those on which Giocondo was employed. In the reign of Francis I., the palaces erected by that sumptuous prince and his nobles attested the magnificence if not the refinement of that age. As a retreat for himself in the immediate vicinity of his capital, Francis built (about 1530) the Château de Madrid in the Bois de Boulogne, whose façades were decorated with coloured enamelled tiles, constituting a species of polychromic decoration. Of that building nothing now remains, it having been taken down at the end of the last century; but another architectural specimen of the same period, the house or casino of Francis I., erected at Moret, near Fontainebleau, has been preserved by being removed to Paris, where it was re-erected in its primitive state, in the Bois de Boulogne, by the architect Biet, in 1823. Of this interesting monument of the Renaissance, which has also some polychromic Robbia-ware decoration, plans, elevations, and sections, are given in Normand's Paris Moderne, but being only in outline, a great deal of the effect is lost in them. The palace of Fontainebleau itself, in its interior at least, records the magnificence of Francis, his taste for splendour, and his liberal encouragement of arts. The Tuileries, as built for Catherine di Medicis, by Philibert Delorme and Bullant, is another great example of French Renaissance when at its best, which has undergone such alterations as to be no longer recognisable. By French writers generally, the style is considered to have risen to its highest point of excellence in the hands of Philibert Delorme [DELORME, in BIOG. DIV.] in the reigns of Henry II. and Francis II.: but it perhaps appears to more advantage in the edifices built in the reign of Francis I.

In Germany, the castle or rather palace of Heidelberg would, if completed, have been a most gorgeous pile in the Renaissance style, as it showed itself in that country; and though now a ruin, the principal portion of the exterior is in sufficiently good preservation to admit of faithful restoration, in a series of architectural engravings. German Renaissance was even more exuberant, not to say extravagant, alike in constructive character and decorative details, than even the French.

The Renaissance edifices of Spain are many of them interesting and striking specimens of the kind. Among them may be mentioned, as deserving of particular notice for the elegant taste it displays, the upper gallery of the cloister of the Convent of Huerta; also the Town Halls of Zaragossa and of Seville; and the Alcaza at Toledo.

RENT, in Political Economy, is defined by Mr. Ricardo to be "that portion of the produce of the earth which is paid to the landlord for the use of the indestructible powers of the soil. It is often, however (he remarks), confounded with the interest and profit of capital, and in popular language the term is applied to whatever is annually paid by a farmer to his landlord." Mr. Malthus ('Prin. of Pol. Econ.') defines rent to be "that portion of the value of the whole produce which remains to the owner of the land, after all the outgoings belonging to its cultivation, of whatever kind, have been paid, including the profits of the capital employed, estimated according to the usual and ordinary rate of the profits of agricultural capital at the time being."

As most modern economists have adopted the main principles of the Ricardo theory, we here give an outline of it, in the words of Mr. Ricardo:—"If all land had the same properties, if it were boundless in quantity and uniform in quality, no charge could be made for its use, unless where it possessed peculiar advantages of situation. It is then because land is of different qualities with respect to its productive powers, and because, in the progress of population, land of an inferior quality, or less advantageously situated, is called into cultivation, that rent is ever paid for the use of it. When, in the progress of society, land of the second degree of fertility is taken into cultivation, rent immediately commences on that of the first quality, and the amount of that rent will depend on the difference in the quality of these two portions of land. . . . With every step in the progress of population which shall oblige a country to have recourse to land of a worse quality to enable it to raise its supply of food, rent on all the more fertile land will rise. . . . If good land existed in a quantity much more abundant than the production of food for an increasing population required, or if capital could be indefinitely employed without a diminished return on the old land, there could be no rise of rent; for rent invariably proceeds from the employment of an additional quantity of labour with a proportionally less return."

Rent, according to the definition which has been given, consists of a surplus which remains after the capital expended in production has been replaced with ordinary profits. This surplus, which constitutes rent, arises, as Mr. Ricardo asserts, from, and is in proportion to, the necessity for resorting to inferior soils or employing capital on the old soil with small returns. To use the words of Mr. Mill, his friend and disciple—"Rent is the difference between the return made to the more productive portions and that which is made to the least productive portion of capital employed upon the land." In a country containing, as every country does contain, land of various degrees of fertility, rent therefore will not be paid until the demands of an increasing population have rendered it necessary to have recourse to the inferior soils. "Thus (continues Ricardo), suppose land, Nos. 1

2, 3, to yield, with an equal employment of capital and labour, a net produce of 100, 90, and 80 quarters of corn. In a new country, where there is an abundance of fertile land compared with the population, and where therefore it is only necessary to cultivate No. 1, the whole net produce will belong to the cultivator, and will be the profits of the stock which he advances. As soon as population had so far increased as to make it necessary to cultivate No. 2, from which 90 quarters only can be obtained after supporting the labourers, rent would commence on No. 1; for either there must be two rates of profit on agriculture, or ten quarters or the value of ten quarters must be withdrawn from the produce of No. 1 for some other purpose. Whether the proprietor of the land or any other person cultivated No. 1, these ten quarters would equally constitute rent; for the cultivator of No. 2 would get the same result with his capital, whether he cultivated No. 1, paying ten quarters for rent, or continued to cultivate No. 2, paying no rent. In the same manner it might be shown, that when No. 3 is brought into cultivation, the rent of No. 2 must be ten quarters, or the value of ten quarters, whilst the rent of No. 1 would rise to twenty quarters. . . It often and indeed commonly happens that before Nos. 2 and 3, or the inferior lands, are cultivated, capital can be employed more productively on those lands which are already in cultivation. . . In such case, capital will be preferably employed on the old land, and will equally create a rent; for rent is always the difference between the produce obtained by the employment of two equal quantities of capital and labour. If with a capital of 1000*l.* a tenant obtain 100 quarters of wheat from his land, and by the employment of a second capital of 1000*l.* he obtain a further return of 85, his landlord would have the power, at the expiration of his lease, of obliging him to pay 15 quarters, or an equivalent value for additional rent; for there cannot be two rates of profit. If he is satisfied with a diminution of 15 quarters in the return for his second 1000*l.*, it is because no employment more profitable can be found for it. . . In this case, as well as in the other, the capital last employed pays no rent. For the greater productive powers of the first 1000*l.*, 15 quarters is paid for rent; for the employment of the second 1000*l.* no rent whatever is paid. If a third 1000*l.* be employed on the same land, with a return of 75 quarters, rent will then be paid for the second 1000*l.*, and will be equal to the difference between the produce of these two, or 10 quarters; and at the same time the rent of the first 1000*l.* will rise from 15 to 25 quarters, whilst the last 1000*l.* will pay no rent whatever." (Ricardo's 'Prin. of Pol. Econ.,' 3rd edit.) Perhaps however the clearest definition of this theory of rent is that given by Mr. Mill, in his 'Elements of Pol. Econ.,' to the last edition of which work we refer for a more complete examination of the subject.

RENT (in Law Latin, *redditus*, "a return") is a right to the periodical receipt of money or something valuable in respect of lands or tenements held by him from whom the rent is due. There are three kinds of rent—rent-service, rent-charge, and rent-seck.

There is rent-service when a tenant holds lands of his lord by fealty and certain rent, or by homage, fealty, and certain rent, or by other services and certain rent. Rent-service therefore implies tenure, and it may be due to the lord of the manor of which the lands are held, or to some other chief (that is, immediate) lord of the fee, or to the reversioner. The right of distress is an incident to rent-service in arrear, so long as it is due to the same person to whom fealty is due. Before the Statute of Quia Emptores (18 Edw. I.), a person might make "a feoffment in fee simple either by deed or without deed, yielding to him and his heirs a certain rent, which was a rent-service, and for this he might have distrained of common right; and if there were no reservation of any rent, nor of any service, yet the feoffee held of the feoffor by the same service as the feoffor did hold over of his lord next paramount." (Litt., 216.) The Statute of Quia Emptores enacted that the feoffee shall hold of the chief lord by the same services by which the feoffor held, and consequently no rent can now be reserved when a man transfers to another all his estate in land. In order that rent-service may now be created, the person to whom the rent is reserved must have a reversion in the lands and tenements out of which the rent is to issue; but any reversion is sufficient. Thus a person who has a term of twenty years may grant it to another, all but one day, and this will leave him a reversion, so that a rent-service may be reserved, with its incidents of fealty and the right of distress. If he assign all his term, reserving a rent, but without a clause of distress in the assignment, he cannot distrain for the rent.

Rent-service therefore which has been created since the Statute of Quia Emptores can only be reserved to the lessor who retains a reversion, and it will belong to the person who is entitled to the reversion. If a man seised in fee simple makes a lease of lands for years, reserving rent, the rent-service is descendible to his heir with the reversion; though all rents which accrue due to the lessor before his death will belong to his personal representatives. A rent-service reserved out of chattels real will of course belong to the personal representatives of the lessor. A rent is now most commonly reserved in leases for years, but it may be reserved on any conveyance which passes or enlarges an estate; and it may be reserved in the grant of an estate in remainder or reversion, or in a grant of a lease for years to commence at a future time.

A rent service may be separated from the reversion or seignory, by the reversioner granting the rent and retaining the fealty: in this case the lands are still held of the grantor, but the rent is due to the grantee; not however as rent service, but as rent seck (*redditus siccus*), so called, "for that no distress is incident to it." (Litt., 218.) If the seignory or reversion is granted, the rent service will pass by the grant, and the grantee is entitled to receive the rent from the tenant from the time that he gives him notice of the grant, together with all rent that had accrued due since the grant, and is unpaid at the time of such notice.

Rent-service can only be reserved to the feoffor, donor, or lessor, or to their heirs, upon any feoffment, gift, or lease; and if the rent is reserved generally, without specifying the persons, it will belong to the lessor, and after his death to those who are entitled to the reversion. Rent is payable at the times mentioned in the reservation, but not till the last minute of the day on which it is payable.

When rent-service is in arrear, the common-law remedy for the recovery of it is by distress. [DISTRESS.] By 4 Geo. II. c. 28, s. 2, every landlord who by the terms of his lease has a right of re-entry in case of non-payment of rent, may, when half a year's rent is due, and there is no sufficient distress on the premises, serve a declaration in ejectment on his tenant, without any formal re-entry or previous demand of rent, and a recovery in such ejectment is final and conclusive, unless the rent and all costs are paid within six calendar months after the judgment in the action of ejectment has been executed. The action may also be stayed before trial, if the tenant will pay or tender to the lessor, or pay into court, all the rent then in arrear, together with the costs. By the common law the lessor has also an action of debt for rent against a lessee for years or at will; and by the statute of Anne (8, c. 14, s. 4) there is also the same action against a lessee for life during the continuance of his estate, which had previously been given for arrears of rent after the determination of the estate (32 Hen. VIII. c. 37). A lessor may also have an action of covenant for rent, either by force of the implication contained in such words as "yielding and paying" rent, or by force of an express covenant to pay, which is seldom omitted in any lease. If the lessee assign his interest in the term, he and his executors, so far as they have assets, are still liable under the covenants to the person entitled to the reversion. The assignee also becomes bound by such of the covenants as run with the land, and is consequently liable to an action upon them. There is also the remedy by action of assumpsit or debt for the use and occupation of land, which action lies without any express agreement for rent (see a remark on this action, 6 A. & E., p. 839).

Rent-service may be discharged in various ways. If the tenant be evicted from the lands demised to him, he is discharged from payment of the rent; and if the lessor purchase the lessee's interest, the rent is also discharged. The lessor may release a part of the rent-service, without releasing the whole.

If the person entitled to the rent-service purchases part of the interest in the land in respect of which rent is due, the rent-service is apportioned according to the value of all the land, and accordingly the tenant is discharged from payment of rent in respect of the part purchased. The person entitled to the reversion may also grant his interest in part of it, and the rent will be apportioned between him and his grantee; for the interest in the reversion is of a divisible nature, and the rent follows the reversion. If the lessee should be evicted out of part of the lands, there will also be an apportionment. Before the late alterations of the law, when the moiety of a reversion was extended on an elegit, the rent was apportioned, and the lessor consequently retained half of it. If a widow is entitled to dower of a reversion, she is also entitled to one-third of the rent reserved upon a lease for years made by her husband.

At common law, if a tenant for life died before the rent became due, which was reserved on a lease that determined by the death of the tenant for life, his personal representatives could not claim an appointment of the rent, nor could the reversioner or remainderman claim such portion as accrued due during the life of the tenant for life. But such an apportionment was given to the personal representatives by stat. 11 Geo. II. c. 19, s. 15. The Act 4 & 5 Will. IV. c. 22, extends the provisions of this Act to rents reserved on leases that determine on the death of the persons who make them, though they are not strictly tenants for life, and on leases of lands held *pur auter vie;* and by the same Act all rents-service reserved on any lease by a tenant in fee or for any life interest or under any power, and granted after the passing of this Act, and all rents-charge and other rents, annuities, &c., made payable under instruments executed, or (being a will) coming into operation after the passing of the Act, shall be apportioned, and a proportionable part thereof, from the last time of payment to the day of the death of the party interested therein, paid to the personal representatives of such party.

A rent-charge is a rent granted out of land either at common law or by the Statute of Uses, with a power of distress for the recovery of the rent. Such rents may be created by the owner of the land who retains the property of it; and they may also be reserved on the alienation of the land. These rents differ from rent service in not being connected with tenure, and the remedy by distress is therefore not an incident to rent-charges, but is created by the same instrument which creates the rent-charge. If no power of distress is given, the rent is a rent-seck. Rent-charge may be created either by deed or by will. Sometimes, by the terms of the grant, the grantee of a rent-charge is empowered to enter on the land and satisfy himself for all arrears out of the profits of the land. When a rent-charge is created under the Statute of Uses (ss. 4, 5) with a power of distress and entry upon the land in case of arrear, the person to whom the rent-charge is given obtains the legal estate in the rent-charge, with all the remedies for its recovery, as he would by a direct grant of the rent-charge; and the same instrument (lease and release) which creates the rent-charge may also make a settlement of the lands charged with the rent. In this way in a marriage settlement a rent-charge may be provided for the wife's jointure.

An estate in a rent-charge may be either in fee simple, or in fee tail, for lives or for years, according to the terms of the original limitation. A rent-charge of inheritance is real estate, and descendible to the heir; but a payment that is due belongs to the person representative. There may also be an estate in fee simple in a rent-service created before the Statute of Quia Emptores. A rent-charge in fee simple is subject to curtesy and dower; and also a rent-charge in tail. But if a rent-charge be created and granted to a man and the heirs of his body, his surviving wife will not be entitled to dower if the husband dies without issue. Until the Act 3 & 4 Will. IV. c. 106, a woman was not entitled to dower out of a rent-charge, unless her husband had the legal estate in it. A rent-charge may be limited by way of remainder; and a new rent-charge may be created to commence at a future time.

A rent-charge may be discharged in various ways. If a man who has a rent-charge out of certain lands buys any part of them, the whole rent is discharged, for it issues out of the whole of the lands; and the consequence is the same if he releases all his right in any part of the land. But a man may release part of the rent-charge without affecting the remainder; and a division or apportionment of a rent by conveying part of it to a stranger is a valid conveyance. If part of the lands which are subject to the rent-charge descend to the grantee, the rent will be apportioned according to the respective value of the two parts of the land.

A rent-seck, as already mentioned, is not, like rent-service, accompanied with a right to distrain at common law; but by the stat. 4 Geo. II. c. 28, s. 5, this distinction in respect of remedy between rent-service and rent-seck is abolished; and the Act also applies to rent-seck created prior to the statute which had been duly paid for three years out of the last twenty years. Other rents, though they belong to one of the three divisions above mentioned, are often distinguished by particular names: thus the rent due from a free-holder is called a chief rent (*redditus capitalis*); the rents of free-holders and ancient copyholders of manors are sometimes called rents of assise, being *assisi*, or ascertained, and also quit-rents (*quieti redditus*), because they are a quittance and discharge of all services.

A fee-farm rent is properly a perpetual rent-service reserved by the crown, or, before the Statute of Quia Emptores, by a subject, upon a grant in fee simple. The purchaser of fee-farm rents originally reserved to the crown, but sold under 22 Car. II. c. 6, has the same power of distress that the king had, and so may distrain on other land of the tenant not subject to the rent.

By the stat. 42 Geo. III. c. 116, in cases where the land-tax has not been redeemed in due time by the owner of the land, it may be purchased by any other person, to whom it will belong as a perpetual rent-charge (though it is called a fee-farm rent in the Act), and the purchaser will have all the remedies for rent reserved on a lease.

By the stat. 3 & 4 Will. IV. c. 27, s. 42, no arrears of rent or of interest in respect of any sum of money charged upon or payable out of land or rent, or any damages in respect of such arrears of rent or interest, shall be recovered by any distress, suit, or action, but within six years next after the same respectively shall have become due, or some acknowledgment in writing given to the person entitled thereto by the person by whom the same was payable; except where there has been a prior mortgagee or other incumbrancer in possession of any land or receipt of the profits thereof within one year next before an action or suit shall be brought by a subsequent mortgagee, &c.; and then the arrears of interest may be recovered for the whole time such prior mortgagee, &c., was in such possession or receipt.

REPEATING CIRCLE. The principle of repetition from which this circle has its name was first explained by Tobias Mayer, professor of the university of Gottingen, in 'Commentarii Societatis Regiæ Scientiarum Gottingensis,' tom. ii., p. 325, for the year 1752. Mayer found that the common surveying instruments were often inaccurate to 5′, while the quadrant, then used in all great scientific surveys, was, from its weight and price, and the trouble required for verifying and adjusting it, scarcely to be considered a portable instrument, but only fit for the observatory. The substitute which he proposed for geodesical purposes may be described briefly as follows:—Suppose a hollow tube fitting upon an axis, to which it can be clamped, when required, by a screw; the axis itself is fixed on the top of a staff. This part of the instrument is exactly similar to a common mounting for surveying compasses, &c., where greater stability is wanted than a ball and socket will give. On the top of the tube a flat bar is screwed, the plane of which is horizontal when the tube and axis are vertical; the bar and tube thus form one piece, which has the shape of a T. A second bar of the same length is placed exactly above the former. This latter bar moves easily, and without shake, on a pin concentric with the tube and axis, and thus can be placed at any angle with the fixed rule, and, as it is supposed, without at all disturbing it. Two fine dots are pricked towards the ends of each bar; the lines joining the dots in each should pass exactly through the axis of motion of the upper bar, and the dots must be equidistant from the centre. When this is so, the four dots will, in every position of the bars, be the angular points of a rectangle, and the equality of the opposite sides can be ascertained by measuring the distance with compasses. Finally, on the top of the upper bar a telescope with cross wires is fixed, the telescope being a little shorter than the bar, that it may not interfere with measurements between the dots.

The mode of measuring an angle with this instrument is as follows:—Let the two objects be R (that to the right) and L (that to the left). Set the fixed bar to some angle from 10 to 20 degrees to the right of R by the motion of the tube on the axis, and clamp the axis-screw firmly; then, by the motion of the upper bar alone, bisect R with the telescope. Take, with a pair of compasses, the distance between the dots, apply the distance to a scale of chords, and you have the angle between the fixed bar and the object R. Call this angle θ. Now, by the motion of the upper bar alone, bisect the object L. It is clear that, if the distance between the dots were again measured, and the angle deduced, as before, from the scale, we should have a measure of the angle required + θ. But instead of measuring at present, let the telescope be brought back on R, *by unclamping the axis-screw and moving the whole instrument on its axis*; when this is satisfactorily performed, clamp the axis, and bisect L exactly as before, by moving the upper bar and telescope alone. The angle between the bars as deduced from measuring the chord between the dots will now clearly be twice the angle required + θ. Let the operation be performed so many times—eight, for instance—that the bars are nearly in their original position with regard to each other, and let the distance between the dots be measured and the corresponding angle be deduced from the scale of chords, which suppose to be ϕ, ϕ being larger than θ. If this last-mentioned angle had been θ exactly, it is clear that the bar would have come round exactly to its original position after having moved through 360°; but as it has besides moved over an angle $=\phi-\theta$, the whole angle moved through is $360°+\phi-\theta$, which is also eight times the angle to be measured: hence the angle subtended at the spectator by R and L is $\frac{1}{8}(360°+\phi-\theta)$. By continuing this process of stepping several times round, there seems to be no limit to the accuracy with which an angle can be measured, except that which depends on the imperfection of the telescope, the indistinctness of the objects, or the uncertain lateral effect of terrestrial refraction. Mayer used a scale of chords, probably because he was thus able to construct the instrument himself, and could dispense with any circular arc or divisions. We do not see that he has noticed one slight inaccuracy, namely, that as the dots lie in different planes, the distance between them is not the actual chord of the angle required, but is the hypothenuse of a right-angled triangle, the altitude of which is the thickness of the upper bar, while the base is the chord required; but this error is easily allowed for, and, when the angle to be measured by the compasses is of a tolerable size, is scarcely worth considering. If we conceive the plane of the lower bar extended and changed into a divided circle, while the upper bar becomes a vernier at each end, we should probably have the instrument Mayer would have proposed, had it been in his power to employ a tolerable mathematical-instrument maker. Mayer says that he invented this instrument eight years before the publication of his memoir.

The reward proposed by the English parliament for any means by which the longitude at sea could be determined, stimulated Mayer to perfect the method of lunar distances. For the successful solution of this problem two things are required—tables correct enough to predict the true place of the moon at any future time, and an instrument for measuring the distance between the moon and star with sufficient accuracy. Mayer fulfilled the first condition by his celebrated Lunar Tables, one copy of which was sent to the Lords of the Admiralty in 1755, and a later, improved up to his death (1762), forwarded by his widow in 1763. For measuring the distance between the moon and star he proposed an instrument similar to Hadley's sextant, but in which the angle can be repeated or multiplied without intermediate readings off, similar in principle to the instrument just described.

Mr. Troughton says (article 'Circle,' Brewster's 'Cyclopædia') that Bird was employed to make reflecting circles after Mayer's idea, but his dividing was so excellent, that the entire circle was thought useless, and the sextant preferred, as having a larger radius, and being lighter and handier.

In 1787 the Chevalier de Borda published his 'Description et Usage du Circle de Réflexion,' in which he proposed a modification of Mayer's circle, so slight that at first sight it would almost seem trivial, but which gives an unquestionable superiority to this above every other form of reflecting instrument when well made and skilfully and *perseveringly* used. We shall return to Mayer and Borda's construction of the repeating reflecting circle in the article SEXTANT, as those instruments cannot be understood until the principle of reflecting instruments has been explained.

The date of the invention of the repeating circle which is the proper subject of this article, is somewhat uncertain: it is later than that of the reflecting circle. One was constructed in 1787, and employed in connecting the meridians of Paris and Greenwich. (See 'Mém. de l'Academ.'; a Memoir by Le Gendre, 1787; and a memoir by Cassini, 1788.) The 'Connaissance des Tems,' An VI. (1797-8), contains the plate and description of a repeating circle which was made by Lenoir for the astronomer La Lande. When the French government undertook the measurement of an arc of the meridian from Dunkirk to Barcelona, the commission to whom this operation was entrusted resolved to employ the repeating circle.

This is one of the most complicated as well as ingenious of existing instruments, and obtained an immense reputation, from being the only instrument employed in the geodesical and astronomical observations of the great measurement of an arc of the meridian, on which the French have founded their modern system of measures, weights, and money. Since that time the construction has been altered by different artists, but not always with advantage.

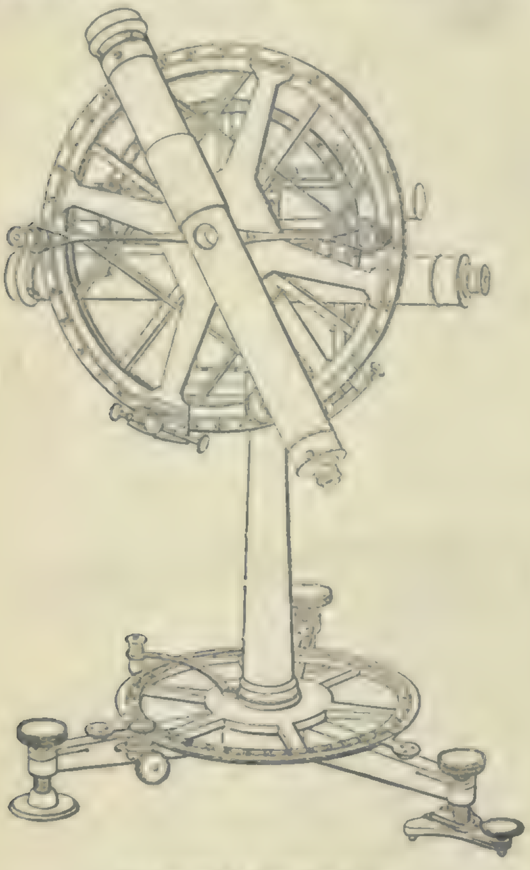

Fig. 1.—Borda's Repeating Circle.

In this figure the general form of the instrument is shown tolerably well, but some of the essential motions are at the back of the circle, and these are drawn on a larger scale in a second diagram. The whole circle turns round on the vertical column, which has an inner axis of steel, with good fittings at the top and bottom. It is usual and proper to make these fittings with great care, but it is not an essential condition to accuracy in the performance of the instrument.

The top of the column finishes in a square bar, to which the upper works and circle are firmly screwed. We shall first describe the motions which are required for astronomical purposes, and point out the rest when the geodesical properties of this instrument are considered. The azimuthal circle is scarcely to be considered a part of the instrument.

The front telescope, its verniers, and clamp, are seen distinctly in front. (*Fig.* 1.) This moves very freely on a spindle within the axis of the circle. There is a level behind, a projecting end of which is seen in the figure. This and its accompanying back telescope are—one a little above and the other a little below the axis of the circle, and revolve on a collar which works on the outside of that axis. These can be fixed in any position by a clamp (also seen in the figure) which embraces the back edge of the circle: the back telescope is for measuring terrestrial angles. Finally, the axis of the circle itself passes through a fitting, on which it also turns freely, carrying telescopes, level, &c., without altering their position in respect to itself. There is a clamp to restrain this motion and fix the circle, the head of which is seen at A, *fig.* 2, and a tangent screw for slow motion at B. This is the weakest and most inconvenient part of the instrument, for the clamp holding so near the axis of motion has little power, and there is scarcely room for getting at the screw head, while the slow motion clamp is out of the way of the observer when he requires it for bisection. The large weight behind is a counterpoise, and the small level above is for setting the circle vertical. There is a clamp at C, which bites on the semicircle to make this adjustment and prevent its being deranged. We will describe the process of observing with the instrument when the object is a star at or near its meridian altitude.

Supposing everything to be adjusted, that is, the axis and circle both vertical, the observer bisects the star with the telescope, he or an assistant having previously brought the level nearly to the corresponding points of its scale. The level is now read off, giving it time to settle if wanted. We suppose its graduation to be in seconds, and reckoned outwards from the centre of the scale. The verniers are read off, the instrument turned half round on the vertical axis, the telescope clamp released, and the star again bisected by the telescope, using its peculiar clamp and tangent screw; and finally, the level is again read off. This operation is precisely the same in all circles having an azimuthal motion, and it is clear that if the verniers were again read off, the difference between the first and second readings would be (after it is corrected for the indication of the level) twice the zenith distance of the star. Let the circle be now reversed, the level clamp and circle-axis clamp be released, and the whole circle moved in its plane till the telescope points to the star, and let the star be bisected again by using the axis clamp and its tangent screw only. The level must be brought back to be horizontal while this is doing, and be actually *clamped* before the final bisection of the star is made. We conceive that this must be done at twice, even by two observers; and it may be done at twice by one, though in a longer time. If the reader has fully understood the process, he will see that the instrument is precisely as at the commencement, except that the telescope and its verniers have travelled over the circle, an arc equal to twice the zenith distance of the star. A repetition of the operation will carry the telescope verniers over four times the distance, and by continuing the process the final arc read off may be made any number of times twice the zenith distance of the star. If the series stops after ten such processes, the arc travelled over is twenty times the simple zenith distance. Let the verniers be now read off, then subtracting the first reading from the last, and dividing by twenty, the result will be the zenith distance of the star, and the errors of division or of reading off will also be divided by twenty. If the number of repetitions which can be taken at one culmination are not thought sufficient to destroy these errors, the series may be prolonged on the following and subsequent nights, starting from the preceding reading without disturbing the verniers, until any number whatever are taken, the only essential condition being that, in reversing, the level is undisturbed both in its attachment to the circle and in its own zero; and that in bringing the telescope on the star by turning the whole on its horizontal axis, the connection between the telescope and circle is permanent. The hour, minute, and second at which each bisection is made are to be noted.

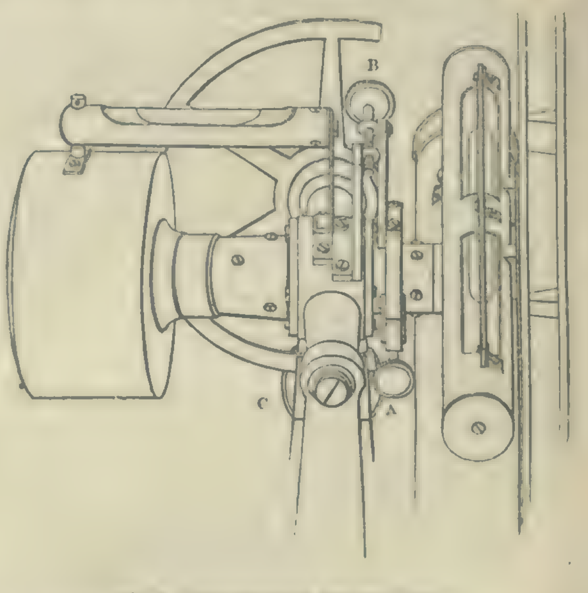

Fig. 2.—Back of Borda's Repeating Circle.

We have said that it is better to read off the level than to attempt to bring the ends of the bubble exactly to the same division, which is really an impossible condition with one observer, and scarcely practicable even with two. The differences should be as small as they can be made with moderate care and in a moderate time; but a well-ground level will measure small arcs better than any graduated limb or even than any small telescope can do, and it is therefore as safe to correct for an error of level as to adjust. The level readings should be registered as towards the object end and eye end, or − and +, along with the times, and the correction may be made to the final arc. It is clear that if the level were always brought to the same divisions, there would be no level error. The effect of a derangement of the vertical axis, which is shown by the level, is calculated as follows:—Let the reading of the level end towards the object be 10″ larger than the reading towards the eye. To correct this, the footscrew towards the observer should be raised 5″, when the two readings will agree; but now the telescope points 5″ *below* its former position, in which it bisected the star correctly. The telescope therefore must be raised, that is, *the zenith distance must be diminished* 5″; hence if 5″ be subtracted from the multiplied zenith distance on account of that observation, the error would be corrected, and so on with every other instance. The rule is, add together all the level readings towards the object end, and prefix −; do the same with those towards the eye end, and prefix +; take their algebraic sum, and divide by twice the number of observations, and the result is the correction to be applied with its sign to the mean zenith distance. This will generally be a very small quantity. As the great difficulty in observing out of a regular observatory is in the reading off, the division of the level might be to every 2″, but numbered as single seconds. These would be better seen, and the divisor of the difference would be the number of observations. When the instrument is very small, and the probable circumstances under which the observer may be placed promise few facilities, the scale may be cut to 10″ only, with bold lines. A mistake of one or two tenths in guessing the subdivisions would be very rare, and scarcely cause a sensible error in the final result.

The circle has been supposed to be adjusted before observing; this is a very simple operation. First place the instrument with the footscrews in their cups, and let that footscrew be towards the observer which rests on the slow-motion piece. This is seen at *fig.* 1, on the right. Place the axis nearly vertical by guess, or, if there is an azimuthal circle, set the plane of that nearly horizontal by a box level. Then place the plane of the vertical circle upright by the cross level, and bring its plane to be parallel with the two footscrews which are *from* the observer; that is, if the object is in or near the meridian, set the circle east and west. Bring the bubble of the main level to the same division at each end by its clamp and tangent screws, and then reverse the instrument (turn it 180° in azimuth). The level is to be brought again to the same divisions, half by its tangent screw, half by screwing the two footscrews an equal quantity in opposite directions. Now turn the circle a quarter round (place it in the meridian according to the supposition), and bring the bubble of the level to its proper position by the third footscrew only. This first attempt at adjustment need only be approximate, but it must be performed over again with considerable nicety. The slow-motion piece is, we believe, due to Borda, and is a very ingenious and useful contrivance for making a coarse screw do the work of a fine one. By placing the footscrew nearer to or farther from the line of the two studs, the elevating power of the screw can be reduced in any proportion, and the finest and slowest motion possible given to the instrument. We have used the slow motion for finally bisecting a star in observing with great comfort. It is more ready to the hand than any other part of the instrument, and the disturbance of the axis is of no importance, as the level must be read off at all events. The approximate bisection is performed by the other screws, and if the observer recollects which way the star is moving, the space through which the instrument is thus moved need only be a very few seconds. The cross level must be originally fixed and adjusted, after the plane of the circle is known to be vertical, either by hanging a plumb-line before the limb, or when the telescope bisects at the same time an object and its image reflected from a fluid. When the cross level is adjusted, the horizontal wire of the telescope may be set right by making a star in the meridian run along it, or else by bisecting a fixed object with it, and afterwards moving the circle in azimuth. The object should run along the wire, and by twisting the wire-plate round may be made to do so.

In the astronomical use of the instrument the azimuthal circle is scarcely required, except to see that you have turned the circle 180° at each reversal. It is convenient to have a coarse division to show this; it is a relief to the eye, and prevents the possibility of catching a wrong star. Any stop which is adjustable and gives notice when the rotation has reached 180° will do. In many of Troughton's repeating circles there is a pin which is pressed by a slight spring against two holes in the azimuth circle, which are 180° apart. This is convenient enough if the observations are confined to Polaris, or a very slow moving star, but wholly insufficient for stars near the equinoctial. It supposes besides that the feet of the instrument are almost exactly placed with respect to the meridian, which is not to be done at once. A bar moving rather stiffly on the vertical axis, and coming against a stop, seems a better contrivance.

For setting to the approximate zenith distance, there is a graduated semicircle attached to the level, which may be seen in the general view. This has its diameter parallel to the level. A slender bar is attached to the object end of the telescope, and passes at the back of the circle; this points out on the semicircle the approximate zenith distance of the star. In many circles which we have seen there are two slips of brass which slide with a little force on the semicircle, and the slight bar above mentioned is brought to *touch* each of these stops alternately. Nothing can be more convenient, but unfortunately, however well the clamps may be made, the contact between the bar and a stop forces the clamp somewhat, and the essential condition of the instrument, that these should be undisturbed, is destroyed. The bar should not be allowed to touch the semicircle at all, but stand freely from it. In this way, by alternately bringing the bar to the equal and opposite divisions, when either the telescope or the level is moved, the telescope will always be at the proper altitude when the level is horizontal. If any one should wish to use the repeating circle as an altitude and azimuth circle, or as a surveying instrument, the wires of the telescope must be set at right angles to the circle axis, by bisecting a distant and distinct object, reading the azimuthal verniers, turning the instrument half round, again bisecting the object, and reading the verniers a second time. If the object be very distant, the azimuth circle may be set to the mean of the readings, and the object bisected by the horizontal screws, which draw the wire-plate; but if very great accuracy is required, either two marks must be set up having the same distance from each other as lies between the two positions of the axis of the telescope, or the angle which this last space subtends at the distant mark must be allowed for. The instrument is not fitted for nice observation with the azimuth circle.

We have now explained the chief astronomical use of Borda's circle, which is that of determining the altitudes of stars upon the meridian by several observations near the meridian. There is a correction to be applied to the mean result, which is easily computed when the approximate latitude and exact time are known. The formulæ and tables required may be found in several works on astronomy, in Schumacher's 'Hülfstafeln,' p. 38, and Baily's 'Tables,' p. 154. The length of time during which the observations may be carried on depends on the altitude of the star and its proximity to the pole. Polaris might be observed safely beyond 36^{m} on each side the meridian, which is the extent of the present tables, and, in these latitudes, stars in or below the equinoctial for fully half an hour on each side. It is supposed that the error of the clock is well known, but even this may be wrong to a small amount without causing much error, if the number of observations on each side the meridian and the hour angles are nearly equal.

The repeating circle may be very well used for getting the time either by equal altitudes, or by absolute altitudes with one or two repetitions. For this purpose there should be three or five horizontal wires, and the instrument should be previously carefully adjusted. The instrument must be moved in azimuth, so that the star passes each wire near the centre, and nothing should be touched which affects the level. For illumination by night, there is an opening with a reflector in the centre of the telescope. This is objected to as weakening the telescope, but the other mode of illuminating by a small central reflector, or outer ring in front of the object glass, is inconvenient. Perhaps by taking a longer hold of the telescope and strengthening the intervening portion of the tube, the former convenient arrangement may be preserved without sensible loss of strength. The repeating circle, on Borda's construction at least, cannot be well employed in observing the sun without very careful screening. The level is so perpetually changing its zero, when exposed to the sun, that there is no possibility of saying what the instrumental zenith is.

One of the first operations which the observer must engage in, is to determine the scale of his level at different temperatures, and then he may, for small deviations, use the indications of the level, instead of worrying himself and losing his time in attempting to produce a perfect adjustment. The value of the scale is thus measured:—Bring the bubble towards one end, bisect a very well defined object with the telescope, and read off both scale and verniers. Then, by the slow-motion foot-screw, bring the bubble towards the other end, bisect the object again by the telescope, and read off the level scale. Now bring the bubble to its original position by the circle-axis clamp, and the telescope on the object by its own clamp, when everything is as at starting, except that the telescope has moved over the circle the sum of the angular motions pointed out by the level. This may be repeated till a sufficiently accurate value is got for the *whole* scale. To try the equality of the divisions of the level, place the foot-screw near the line passing through the studs of the slow-motion piece, and note the motion of the level for every *whole* revolution of the screw.

For geodesical purposes Borda's circle is an excellent instrument, as the great French survey proves, but as the same advantages can be obtained by a different application of the repeating principle, it is now but little used. For an account of its employment and the directions for its use we refer to Delambre's 'Méthodes Analytiques pour la Determination d'une Arc du Méridien,' &c., Paris, An VII.; in the 'Discours Préliminaire,' by the same author, contained in the 'Base du Système Mètrique Décimal,' vol. i. Paris, 1806.

Borda's repeating circle possesses two most valuable properties: mere errors of division may be diminuted by sufficient patience; and the fatigue of reading off the divisions, the most ungrateful part of an observer's task, is greatly reduced. Hence, it may be asked, why is not the repeating circle in general use as a portable astronomical instrument? We should answer that, in the first place, the construction of Borda is by no means satisfactory for an *astronomical* instrument; it is weak, and heavy, and rickety. But if a *portable* astronomical circle is wanted, and to this class of instruments we should confine the repeating circle, we think the following alteration should be adopted. The telescope hangs loosely from its centre,[*] and whatever care may be taken by the artist, the flexure of each end must be considerable, probably different, and possibly varying from time to time with variations in the temperature. It should be grasped by two strong collars near the ends of a diameter of a vernier circle, and the telescope might then be safely extended three or four inches each way beyond the divided circle. Again, the axis clamp which holds the vertical circle should be fixed on the pillar and embrace the rim of the inner circle, the clamp of the level (for no second telescope is wanted) might be at the back, above, and quite out of the way. The whole circle should be brought as close to the upright pillar as possible, and perhaps its axis had better be fixed by the maker permanently at right angles to the pillar. This would take away much weight and give great firmness to the whole instrument.

It must however be admitted that unless there are two intelligent observers, or unless the base on which the instrument stands is so steady as to prevent the possibility of any derangement when the observer moves from the telescope to read the level, that errors may creep in, though not, as it seems to us, greater than in all other instruments *not* reflecting. We have previously cautioned circle observers, and the warning cannot be too strongly pressed upon our countrymen at least, that the *level* must *always* be noted contemporaneously with the *bisection* of the star. If the foundation of the instrument is immoveable, this will be the same as the level a minute after bisection, and so only one observer be required. But if the position of the instrument is affected by the weight or motion of the observer, the *level* after bisection is no test of the position *at* bisection, and two observers are absolutely necessary. In Borda's repeating circle, where the clamp is necessarily imperfect from the shortness of its bearing, it is impossible to move the front telescope without shifting the circle a little at the same time; but this is of no importance, for the level shows the change, and the reading off of the level, when properly applied, corrects this error.

In judging of the repeating principle as applied to any instrument, attention should be paid to the perfect independence of the telescope and level with respect to each other, and to their perfect connection with the circle when they are clamped to it. In some instruments a sort of repetition has been attempted by having the circle turn freely on the telescope axis, and clamping it alternately to the telescope and to a vernier circle which carries the level. It seems difficult in any such construction to secure the immoveability of the circle while clamping and unclamping is going on, and the construction has, we believe, gone out of use. There are some precautions which should be observed in every repeating circle, which we shall describe in reference to Borda's construction. Besides the perfect independence of the level, the telescope with its verniers and clamps should be perfectly self-balanced, so as not to apply any force to the clamp in any position; the telescope should be moved on the circle by two fingers pressing in opposite directions towards the extremities; the circle should be turned in its own plane by laying hold of the circle itself, and so gently that no jar can take place, or any springing back or forward of the telescope or its verniers from the moment of inertia: finally, the level must have time to settle before it is read off. When these precautions are duly observed, great accuracy may be obtained; in two instances, to our knowledge, where the latitude has been determined by unexperienced but intelligent observers, the results even of a single night have come within 1" of the truth.

It may be worth mentioning that with the circle of Borda the measurements may be made by moving the telescope *contrary* to the order of divisions, that is, if the first observation is made with the face to the right hand instead of the left. There is no advantage in this modification, except perhaps that, as the screws are handled a little differently, any discrepancy between an angle measured in the two ways would show an error in one or both the methods. It would be advisable, where several series are taken, to vary the direction in which the telescope is brought to its new position, and that in which the circle is turned upon the star. The tangent screw might be worked either constantly one way or the other, or alternately, but we should not expect any sensible difference in the results if the instrument is well made and the observers careful. If two steady observers can be found, the double altitude of any star may be repeated, with the genuine Borda and its two telescopes, exactly as a terrestrial angle, that is, by measuring the angle between the star seen directly and by reflexion from mercury. This would in theory appear to be the most perfect application of the instrument, as flexure has no effect upon the angle measured, being equal and in the same direction in both positions of the telescopes. The level is not wanted for this observation at all, but the circle must be set truly vertical. A single observer might indeed make the same observation with one telescope, as the level would show and measure any shifting of the circle. And here again the effect of flexure is eliminated from the observed double altitudes. Finally, double nadir distances may be observed of a star reflected from a mercurial horizon, exactly as double zenith distances are observed in the ordinary method. This last species of observation may have the advantage of being sometimes more convenient, but the chief reason why it is pointed out is, that the effect of flexure upon double nadir distances is equal, but in a contrary direction, to its effect on double zenith distances; the observer has thus an easy mode of ascertaining whether flexure exists, and of measuring its amount and law. We suppose that the apparent nadir distance of a reflected star is the same as the zenith distance of the star seen directly. The horizontal points of all the large circles which we know, vary to some extent with the altitude of the star observed, which seems contrary to what is here supposed. This last mentioned discrepancy is one of the most perplexing points in modern practical astronomy. The amount is, however, so small as scarcely to vitiate sensibly any conclusion drawn from reflected observations with so small an instrument as a repeating circle.

What precedes refers almost entirely to the repeating principle when applied to measurements in altitude. Instead of the circle of Borda and its two telescopes, later artists have given a motion in azimuth to their theodolites, in addition to the motion of the telescopes and verniers, by which the angle can be measured precisely as in Mayer's original instrument. But in several instruments which we have seen there is a considerable probability of disturbing the circle clamp while moving the telescope or using its tangent screws. It is to secure the detection of any similar motion that a watch telescope, as it is called, is frequently added to English theodolites, and is indeed required for many, spoiled as they are by an unnecessary adjustment to zero, to save indolent or ignorant surveyors a simple subtraction. A watch telescope can scarcely be applied to a repeating theodolite, and we think that the repeating tripod may be so made as to be free from any objection. This was first constructed by Mr. Dollond on the suggestion of the late Astronomer Royal, and has been found very useful in the trigonometrical survey of Ireland.

The three foot screws of an ordinary theodolite are placed in the three notches which are seen on the table of the tripod. This upper part turns heavily on a stout short centre, it is fixed by a clamp at A, and there is a tangent screw at B for giving slow motion. The steady action of the tangent screw is secured by a spring at C. It is evident that if, in using an ordinary theodolite, R (the right hand object) is first bisected, the circle read off, and then L (the left hand object) is bisected, the circle being again read off, that the difference between the two readings is the angle to be measured, *if the instrument has not been shifted*, and if the bisection, reading off, &c., are perfect. Now suppose the whole instrument to be taken up and set down exactly concentric with its first position, without any other alteration, but with the telescope on R; if L be a second time bisected, the difference between this latter and the preceding reading will be also the angle to be measured, and therefore the vernier will have passed over twice the angle, reckoning from the beginning. If, instead of this impracticable taking up and setting down again, the stand on which the theodolite rests can be turned round concentrically so that R is bisected by the telescope, the theodolite itself being untouched, it is clear that the operation is equivalent to that just described, and consequently that the telescope being brought on L by its own motion, the measure is obtained of twice the angle required, and the process may be continued *ad libitum*, until the errors of read-

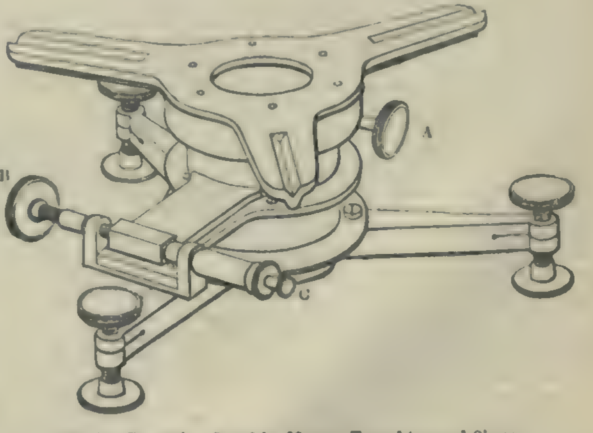

Fig. 3.—Repeating Stand by Messrs. Troughton and Simms.

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[*] If the object and eye end bend equally, there is no alteration in the direction of the line of sight; the only evil is that the oblique incidence of the rays on the object glass deforms the image when the obliquity is considerable. The German artists of Reichenbach's school apply levers to telescopes hung by the middle, in order to counteract flexure. We prefer, on the whole, obtaining a maximum of stiffness, and then determining the effect of flexure which must be allowed for. There is no possibility of avoiding the investigation in any case where accuracy is demanded. Gambey takes a longer hold of the telescope, but in providing a motion for surveying when the circle is horizontal, we think he has lost something in stability when the circle is vertical.

ing off and of division are eliminated. The only precaution to be observed is, that the stand must receive no angular motion from the motion of the telescope, and this is easily effected by giving a certain massiveness to the stand and a considerable heaviness to its motion, while the telescope and its verniers revolve as lightly as possible. The observer should satisfy himself as to this perfect independence of the two motions and the stability of his repeating tripod by taking a set of twenty repetitions of an angle, always moving the telescope forward in the order of the divisions, and a second set of twenty of the same angle, carrying the telescope round the contrary way. The two results should agree if the stand has no motion; and if they do not, the upper motion must be lightened or the lower be loaded till they do agree. We should not feel satisfied to use the repeating stand if a motion of the telescope a little ruder than necessary affected its position although unclamped; and the stand which is here figured fulfilled this condition very well with a 12-inch theodolite. As the absolute coincidence of the axes of the tripod and theodolite cannot be obtained, the angle should be repeated at least once round the circle, and, if the case requires it, until the multiple angle is very nearly equal to one, two, or more circumferences. The original repeating tripod as designed by Mr. Pond was considerably higher than that figured here. (See Pearson's 'Practical Astronomy,' plate xxix., fig. 7, and vol. ii., p. 513.) A little greater nicety is thus given to the adjustment of the vertical axis of the tripod, which is not necessary, and the snugness of the present stand is, we think, more than an equivalent. The axis of the tripod must first be set vertical, either by a level of its own or the theodolite level, exactly as is described in the adjustment of the vertical column of Borda's circle. For the subsequent adjustments, &c., of the theodolite, see THEODOLITE.

REPETEND, the part of a CIRCULATING DECIMAL which is perpetually repeated. The word, however, means simply *to be repeated*, and is so little used in the above sense that it might be advantageously employed with more generality.

REPLEVIN (*delivrance de namps, replegiatio*). In the middle ages the performance of legal duties was enforced by taking the person, the lands, or the goods of the defaulter into the custody of the party authorised to enforce the performance of such duties. When such a taking was effected, the party was said to be distrained (*districtus*, put under compulsion), by his body, his lands, or his goods, to do the act in respect of which he was supposed to have made default. [DISTRESS.]

Upon a distress being effected, the body, land, or goods, as the case might be, of the distrainee remained in the custody of the distrainor until the act for which the enforcing of the distress had been made was performed: unless the distrainee brought the question of the legality of the taking before a competent tribunal, in which case he might either await the result of his legal proceedings, or, if he was desirous of obtaining a more speedy liberation of the thing distrained, he might replevy it by giving a pledge or security to replace it in the custody of the distrainor in the event of the legal decision being in favour of the latter.

The alleged defaulter might contest the legality of the taking in an action of trespass. [TRESPASS.] But in this form of action he could recover damages only. He would not be entitled to the liberation of his body, lands, or goods, as the case might be, pending the suit; nor indeed when the suit had terminated in his favour, could he by any proceeding which could be resorted to in the action of trespass be relieved from the distress. The remedy by which a party was to recover his liberty or the property distrained, and also damages for the temporary detention, was an action of replevin. Where the person of the plaintiff was taken, his remedy was by an action of replevin in a peculiar form, which, taking its denomination from the writ by which it was commenced, was called *de homine replegiando*. This proceeding was however surrounded by so many difficulties, rendered perhaps indispensable by the necessity of preventing criminals from using it as a means of evading justice, that it has now become obsolete in England, parties preferring to obtain their discharge by the more summary process of habeas corpus. [HABEAS CORPUS.] The great mass of the cases of *homine replegiando* in the old law books arose upon the seizure and detention of persons whom the parties seizing claimed as their fugitive villeins [VILLEIN], and this process was frequently resorted to in Jamaica and other slave colonies. The seizing of the lands of a defaulter by way of distress has long ceased to be practised.

Formerly not only lands but incorporeal hereditaments were the subjects of replevin, of which a remarkable instance occurred in the reign of Edward III. ('Parliament Rolls,' vol. i., 45.)

The third form of replevin, and the only one now in use, is replevin of goods, called in the old statutes *replegiari de averiis*, cattle (in law Latin, averia) being the species of goods which usually formed the subject of a distress.

If the goods of a party were taken out of his possession against his will, he was entitled to a writ of *replegiari facias*, by which the sheriff was required to cause the goods to be replevied, that is, restored to the owner upon his giving pledges for the prosecution of his action, and for the return of the goods to the distrainor in case a return should be adjudged. As the right of the party from whom the goods are taken to have the possession restored to him by replevin, depends upon the property belonging to him—if the taker of the goods claim them as his own property, the power of the sheriff is suspended, until the party has sued out a writ *de proprietate probandâ*, by which the sheriff tries whether the goods are the property of the plaintiff or of the defendant; and if they are found to be the property of the plaintiff, then to replevy them; if of the defendant, the plaintiff's claim to be restored to the possession of the goods remains in suspense until the termination of the action.

A replevin does not lie for goods taken in execution, or for goods seized for a debt to the crown. In a very intemperate speech, addressed by Hyde, afterwards Lord Clarendon, to the House of Lords, upon a charge against the barons of the Exchequer, for enjoining the sheriffs of London not to execute a writ of replevin of goods seized by the officers of the custom-house in respect of unpaid tonnage and poundage, he is stated to have said, in the course of his argument, "We all know a replevin lies against the king, if the goods be (be not?) in his own hands." ('Rushworth,' part 2, vol. ii., 1361.) Though this strange assertion has been regularly transcribed by succeeding writers, it appears to be altogether unfounded. The replevins sued out for goods seized in respect of tonnage and poundage would issue against the officers as for goods seized by them in respect of debts claimed to be due to the crown. But goods seized for the king's debts cannot be replevied without the special mandate of the king or of the barons of the Exchequer. Still less could replevin be brought in respect of goods in the actual possession of the king, and upon an allegation of their having been wrongfully taken by him.

Replevin does not lie for goods taken in a foreign country, though afterwards imported here.

If upon a distress taken by the superior landlord upon premises in the possession of an under-tenant, the mesne or intermediate tenant puts his cattle in the place of those distrained, as by law he was allowed to do, he might replevy the goods so substituted, though the latter were never distrained.

Replevin lies notwithstanding an express agreement that the landlord shall be at liberty to distrain and hold the goods against pledges (that is, notwithstanding a tender of pledges) until the rent be paid; for goods cannot be made irreplevisable by the mere agreement of the parties.

Executors may maintain replevin for the goods of the testator taken in his lifetime, and a husband may bring replevin alone without naming his wife, for the goods of the wife taken before the marriage; as the property in the goods passes to the executors, and to the husband respectively, notwithstanding the seizure and detention.

A person may in some cases support a replevin without being the owner of the goods, as where the plaintiff is the bailee of the goods taken. [BAILMENT; PLEDGE.]

The writ of *replegiari facias*, which must have been sued out of the Court of Chancery, was attended with great inconvenience and delay at a period when the chancery followed the person of the king, and hence it was provided by the statute of Marlbridge, (1267) that the sheriff should, after complaint made, deliver the goods without hindrance or refusal of him who took them, and by 1 and 2 Philip and Mary, c. 12, every sheriff was required to appoint four deputies dwelling not above twelve miles distant from one another, to make replevies and deliverance of distresses. Under these two statutes distresses continued to be replevied, until quite recently; when by the statute 19 & 20 Vict. c. 108, the powers of the sheriffs were transferred to the registrars of the County Courts [COUNTY COURTS], who now grant replevins, and take security from the replevisor for the prosecution of an action either in the County Court or in one of the superior courts to try the validity of the distress. This bond is taken under the statute 11 Geo. II., c. 19, s. 23, requiring sheriffs and other officers having authority to grant replevin, in every replevin of a distress for rent, to take from the plaintiff and two responsible persons as sureties a bond in double the value of the goods distrained, with a condition for prosecuting the suit with effect and without delay, and for duly returning the goods and chattels distrained in case of a return being awarded.

By this statute this bond may be assigned to the avowant (the party who took the distress in his own right), or to the person making cognizance (the party acknowledging the taking of the distress on behalf of some other person), and the assignee may sue upon it in the event of the condition of the bond not being performed.

In the action which follows the replevin, the plaintiff declares against the defendant for the taking of the goods and chattels of the plaintiff, at such a time and in such a place, and claims damages. To this declaration the defendant may plead non cepit, whereby he admits that the goods belong to the plaintiff, and denies the taking only; or he may plead that the goods do not belong to the plaintiff, thereby admitting that he took and detained them.

But in ordinary cases, the defendant avows in his own right, or makes cognizance as bailiff to his employer, for rent, or for some other duty or cause, for which a distress is allowed by law [DISTRESS], in doing which he may set up any ground of distress, though differing from that expressed at the time when the distress was made.

The plaintiff may reply to the defendant's plea as in other cases [PLEADING]; but inasmuch as an avowant, or a person making cognizance, is not merely a defendant, but a party seeking to recover something, the plaintiff's answer to an avowry or cognizance, which is in the nature of a declaration for the right or duty withheld, is called a plea in bar to such avowry or cognizance; the defendant's answer to which plea or bar is called a replication.

Where there is judgment for the defendant, or the plaintiff is nonsuited, the judgment directs that the defendant shall have the goods restored to him without being again subject to being replevied, which is called a return irreplevisable.

If upon a replevin, or upon a writ of retorno habendo after judgment, the sheriff returns that the cattle, &c., are driven away (eloigned, elongata) a writ may issue commanding the sheriff to make reprisals by taking the cattle, &c., of the distrainor, and to detain them until he is ably to replevy the cattle, &c., of the distrainee. This process, which is now nearly obsolete, was called a capias in withernam, or a capias by way of counter-taking, from *wither* (against; in German, *wider*) and *nam*, a taking or distress. A special action of trespass also lies for removing a distress so that it cannot be replevied. This latter offence was formerly called a "vee," or "vetitum namium," by which term is to be understood, not, as might be supposed, a forbidden distress, but a distress forbidden or refused to be replevied." (2 'Inst.', 140.)

If after goods have been replevied, and before the suit has been decided, the defendant makes another distress for the same cause, such second distress is called a recaption, and the course is to sue out a special writ for the restoration of the goods and for the punishment of the recaptor; since, whether the first taking was right or wrong, the defendant is not justified in thus anticipating the judgment of the court. It is not material whether the second taking be of the same goods or of other goods, provided they belong to the same party, and are taken for the same cause; but if the landlord distrain the goods of A, who replevies, and afterwards, finding the goods of B upon the land, he distrains them for the same rent, no writ of recaption lies. B can only replevy or bring an action of trespass or trover.

At common law, if the plaintiff was nonsuited, although the defendant became entitled to a return of the goods, yet the judgment was not that the return should be irreplevisable, as in a judgment upon a verdict where the right had been tried. The plaintiff might have again sued out a replevin, and so after several successive nonsuits. To put an end to this vexatious proceeding, the statute of Westm. II. c. 2, gave the plaintiff a writ of second deliverance instead of a new replevin, in which, if the plaintiff in any manner fail in his suit, the defendant will have judgment for a return irreplevisable. In other respects the proceedings in the action of second deliverance are similar to those in the action of replevin.

REPLICATION. [PLEADING.]

REPORTS (in Law) are relations of the proceedings of courts of justice. They usually contain a statement of the pleadings, the facts, the arguments of counsel, and the judgment of the court;—the object being to establish the law, and prevent conflicting decisions, by preserving and publishing the judgment of the court, and the grounds upon which it decided the question of law arising in the case.

The earliest reports extant are the 'Year Books.' It is said that some few exist in MS. of the reign of Edward I. and a few broken notes are to be found in Fitzherbert's abridgment. A series of these commences, and are now printed, from the reign of Edward II. They were published annually, which explains their name, from the notes of persons, four in number, according to Lord Coke, who were paid a stipend by the crown for the purpose of committing to writing the proceedings of the courts. These early accounts of cases are very short, abrupt, and often confused, especially from the circumstance that it is frequently difficult to ascertain whether a judge or a counsel is speaking.

The Year-books continue, with occasional interruptions in their series, down to the reign of Henry VIII. The omission during the time of Richard II. has been attempted to be supplied by Bellewe, who collected and arranged the cases of that period which had been preserved by other writers. The Year-books are wholly written in Norman-French, although by the 36 Edw. III., stat. 1, c. 15, it was enacted that all pleadings should be in the English language, and the entries on the rolls in Latin. This dialect continued indeed to be used as late as the 18th century; the last which appeared were those of Levinz and Lutwyche; the former in 1702, the latter in 1704. The Year-books of later date have more continuity of style and fulness of discussion; cases are cited, and the decision of the court is given at greater length, with more solemnity and clearness. About the end of the reign of Henry VII. it is probable that the stipend was withdrawn. Only five Year-books exist for the ensuing reign, and none were published after it. Their place was shortly afterwards supplied by reports compiled by private individuals, but subject for some time to the inspection of the judges, whose testimony to the fitness of the reporter is prefixed to the Reports. This however soon became a mere form, as appears by the statement of Lord-Keeper North, who speaks slightingly of the Reports in his time as compared with his favourite Year-books.

During the reign of Henry VIII. and his three successors, Dyer, afterwards chief-justice of the Common Pleas, took notes as a reporter. Benloe and Dalison were also reporters in these reigns. In the time of Elizabeth many eminent lawyers reported the proceedings of the courts, and, from the ability with which they acquitted themselves, added to the previously unsettled state of the law, the Reports of about this period have acquired very great authority. Anderson, Moore, Leonard, Owen, Coke, and Croke, all lived about this time. But the first printed accounts of cases published by a private hand are those of Edmund Plowden, the first part of which appeared in the year 1571, under the title of 'Commentaries.' A few years afterwards the executors of Dyer published the notes of their testator under the express name of 'Reports,' being the first published under that title. These were followed, in 1601 and 1602, by those of Sir Edward Coke, which, from their excellence, have ever been dignified by the name of 'The Reports.' During this time reporters did not, as they have done in more modern times, confine themselves to one court. In the same volume are found reports of cases in chancery, in the three superior courts, the court of wards, &c. During the reign of James I., Lord Bacon and Sir Julius Cæsar suggested to the king the appointment of two officers for the purpose of taking notes and minutes of proceedings in the courts. James acceded to the suggestion, and a copy of his ordinance for their appointment, at a salary of 100*l*. each, is extant. (Rymer's 'Fœdera,' 15 Jac. I., 1617.) The ordinance does not, however, appear to have been acted upon, and Reports continued to be compiled and published by private hands only.

The English language was first used by reporters about the time of Elizabeth. Lord Coke employed it in his 'Commentary upon Littleton.' In his preface he states why he thought it convenient to do so; and adds that his conduct was not without precedent. From the period of Elizabeth down to the present, Reports have been published of the proceedings in all the courts. Coke, in his day, thought the following distich applicable:—

> "Quæritur ut crescunt tot magna volumina legis;
> In promptu causa est, crescit in orbe dolus."

This is curious as evidencing the number and fecundity of reporters at that time. North also complains of the great number of Reports.

(Coke's *Reports*, Preface to part 3; Dugdale's *Origines Juridicales;* Reeves's *History of the English Law.*)

REPRESENTATION. [DESCENT.]

REPRIEVE (from the French *repris*, withdrawn), in criminal law, means the withdrawal of a prisoner from the execution and proceeding of the law for a certain time. Every court which has power to award execution, has also power, either before or after judgment, to grant a reprieve. The consequence of a reprieve is, that the delivery or the execution of the sentence of the court is suspended. A reprieve may proceed from the mere pleasure of the crown expressed to the court, or from the discretion of the court itself. The justices of jail delivery may either grant or take off a reprieve, although their session be finished, and their commission expired. A reprieve proceeding from the discretion of the court is usually granted when, from any circumstance, doubt exists as to the propriety of carrying a sentence into execution. This doubt may be created either from the unsatisfactory character of the verdict, the suspicious nature of the evidence, the insufficiency of the indictment, &c., or from the appearance of circumstances favourable to the prisoner. When a reprieve has been granted with a view to recommend to mercy a prisoner capitally condemned, a memorial to that effect is forwarded to the secretary of state, who recommends the prisoner to the mercy of the crown. Where it has been granted by reason of some doubts in point of law as to the propriety of the conviction, the execution of the sentence is suspended until the opinion of the judges has been taken upon it. The sentence is then executed or commuted in accordance with their opinion.

There are two cases in which a reprieve is necessarily granted. One is where a woman who has been capitally convicted pleads her pregnancy in delay of execution. Where such a plea is made, the judge must direct a jury of matrons to inquire of the fact; and if they find that she is quick with child, the execution is delayed, either till after her delivery, or proof by lapse of time that she was not pregnant. The other is where a prisoner appears to have become insane between judgment and the award of execution. In such case a jury must be sworn to inquire whether he really is insane. If they find that he is, a reprieve must be granted.

If the reprieve is sent by the secretary of state, it is under the sign manual of the sovereign.

REPUBLIC is derived immediately from the French *république*, and ultimately from the Latin *res publica*. The Latin expression *res publica* is defined, by Facciolati, to be "res communis et publica civium una viventium," and corresponds very closely with the English word *commonwealth*, as used in its largest acceptation for a political society. The Latin word *res publica* might be applied to a community under a monarchical government; thus Augustus is said in a passage of Capito, a Roman lawyer, to have governed the *res publica* (Gellius, xiii. 12); the word, however, was more applicable to a society having a popular government than to a society having a monarchical government; thus Cicero denies that the name of *res publica* can be properly given to a community which is grievously oppressed by the rule of a single man: "Ergo illam rem populi, id est rem publicam, quis diceret tum, quum crudelitate unius oppressi essent universi; neque esset unum vinculum juris, nec consensus ac societas coetus, quod est populus" ('De Rep.,' iii. 31).

A *republic*, according to the modern usage of the word, signifies a political community which is not under monarchical government, or, in other words, a political community in which one person does not possess the entire sovereign power. Dr. Johnson, in his dictionary, defines a republic to be "a state in which the power is lodged in more than one." Since a republic is a political community in which several persons share the sovereign power, it comprehends the two classes of aristocracies and democracies, the differences between which are explained under ARISTOCRACY and DEMOCRACY.

The word *republic* is sometimes understood to be equivalent to *democracy*, and the word *republican* is considered as equivalent to *democrat*; but this restricted sense of the words appears to be inaccurate; for aristocratic communities, such as Sparta, Rome in early times, and Venice, have always been called republics.

REPUBLICATION. [WILL AND TESTAMENT.]

REPULSION is that power by which bodies or the particles of bodies are made to recede from one another. Both attraction and repulsion exist in all the particles of material substances, and seem to be properties by which those particles act upon one another when not in contact. The cause of these actions will probably be for ever unknown to us; and the terms are only applied in conformity to the phenomena exhibited. At all sensible distances, bodies, small and great, except in certain states with respect to electricity or magnetism, attract one another; and the intensity of the attraction varies inversely as the square of the distance between the bodies. But the phenomena of light, and of elasticity in general, show that at distances which are not appreciable by the eye (perhaps such as are less than $\frac{1}{2000}$ inch) both attractions and repulsions take place. [ATTRACTION.]

In his researches concerning the phenomena of light, Newton, having brought at one time a hair, and at another the edge of a knife, near a small beam of light in a darkened room, found that the particles of light were made to deviate from the rectilinear direction, as if attracted by a force which diminished with the distance of the ray from the hair or knife. The shadow of the latter was bordered with three coloured fringes, of which the nearest to it was formed by inflected rays passing at a distance rather greater than $\frac{1}{[illegible]}$ inch from the knife-edge; and the second and third fringes by rays inflected respectively at greater distances. ('Optices,' lib. iii.) [DIFFRACTION OF LIGHT.] From these phenomena Newton was led to the opinion (which he proposes as a query) that all material bodies might be assemblages of particles in equilibrio between their mutual attractions and repulsions. He imagined also that a subtle ether, pervading material bodies, was the immediate agent in producing such attractions or repulsions, together with all the circumstances of cohesion, and also those of chemical, magnetical, and electrical actions. The phenomena of nature seem to justify the supposition than an ether pervades all bodies; but it must be admitted that the hypothesis of Newton only removes the difficulty concerning the actions of the particles of bodies a step further, since we are equally at a loss to account for the existence of the powers in those particles, and in the ether itself.

The reality of a distance between the particles of bodies, whether solid, fluid, or gaseous, admits of no question; for the differences in the densities of these classes of bodies can only be conceived to arise from the different extent of the intervals between the particles. [HEAT.] By the process of cooling, all bodies, with certain exceptions in particular cases, become contracted in volume; and the mixing of two given volumes of different fluids (as water and sulphuric acid) produces a volume less than the sum of the two separate volumes. These effects manifestly depend upon the approach of the particles to one another, and are therefore inconsistent with the supposition that they were originally in contact.

It is natural to ask if there be such a thing as mathematical contact in nature, and it may be answered that we have no evidence of such a condition. [COHESION.] Besides the continual diminution of volume produced in the cooling of bodies, the Newtonian experiment of pressing a convex lens of glass upon the surface of a glass mirror affords evidence that the lens, at the point of nearest approach, and under a very great pressure, is not in contact with the mirror; and it has been supposed that the distance between them, at that place, is then not less than $\frac{1}{[illegible]}$ inch. (Robison, 'Mechan. Phil.') It seems to follow that a vast force of repulsion must be in action between the particles of bodies when they are as near together as mechanical power can bring them; and it can be easily conceived that such repulsive force may be the immediate cause of the sensation of touch.

It has been said that the mixture of certain different fluids produces a diminution of volume; but it must be observed that a contrary effect frequently takes place. Some of the metals, when mixed together in a melted state, produce a volume greater than the sum of the component volumes; and melted metals, on becoming solid, like water on being frozen, expand in volume. The latter effect may arise from the crystals, on being formed, placing themselves across one another so as to leave comparatively large intervals; but the other can only be caused either by a diminution of the attractive power which the particles exert on one another, or by its being changed into a power of repulsion. One of these latter circumstances must also be the cause of the great augmentation of volume which takes place when the components of some bodies are disengaged from each other. It is said that if the parts of olefiant gas were separated, the sum of the separate volumes would be four times as great as the volume of the compound; that is, two volumes of hydrogen and two of carbon vapour are condensed in olefiant gas into the space of one volume.

It is right to observe that the word *repulsion* is often applied to phenomena which are in reality the results of attraction. A small quantity of quicksilver being laid on a glass plate assumes a spherical form, instead of spreading over it in a thin surface; and this was once supposed to arise from a repulsive power in the glass, whereas it is owing to the attraction of the particles of quicksilver for one another being greater than the attraction of the glass for the quicksilver. Again, when a small sewing-needle is placed on the surface of water, it remains there without sinking, and the water is depressed about the needle as if it were repelled by the steel; in fact, however, the trough is caused by the weight of the needle, which displaces the particles of water, but is not great enough to overcome their attraction for each other. Also, when two balls, one of them of glass, which is capable of attracting water, and the other of burnt cork, which is not, or only in a very small degree, are placed near one another in water, the latter seems to be repelled from the former; but the cause of the phenomenon is that the ring of elevated water about the glass assumes on the exterior a conical surface, so that when the cork ball is brought near enough to the other to be partly on the slope, it immediately slides off by its gravity.

The elasticity of bodies is a result either of attractive or repulsive powers, or both. For example, when a steel rod is bent, the particles on one side will be forced towards, and on the opposite they will be drawn from one another; in recovering itself, a force of attraction will be exerted on the latter side, and of repulsion on the other; and this may be considered as an evidence that in the insensible spaces between the particles of bodies attractions and repulsions prevail according as the distances between those particles are varied. While the change of figure in the rod is small, so that the displacement of any two particles is but a small part of their whole distance from one another, the attractions and repulsions exerted by the force applied are proportional to that force; and upon this principle depends the observed isochronism in the oscillations of a watch-balance, whatever be the extent of the arcs of vibration. The expansions of solids and fluids by heat, and the elastic powers of gas at different temperatures, are consequences of the repulsions residing in the particles of caloric, or induced by the latter in those of the bodies with which they are combined. [ELASTICITY; GAS; HEAT.] The repulsive power existing in the air which is condensed in nitre, produces, on being combined with heat, a velocity of expansion equal to about 7000 feet per second; and the force of pressure resulting from it is thought to be equal to 2000 times the pressure of the atmosphere. (Hutton, 'Tracts.') The repulsive force which produces some of the electric explosions in the atmosphere is supposed to be much greater. But the forces both of attraction and repulsion by which the particles of light are deflected from their course when they impinge on a refracting or reflecting surface are enormous; and Sir John Herschel computes that they exceed the force of gravity in the ratio of 2×10^{44} to 1. This is on the hypothesis of radiation; and that philosopher observes that on the undulatory hypothesis the numbers are equally high.

The circumstances of electrical attractions and repulsions are shown in the article ELECTRICITY; and the results of experiments prove that the intensities of these forces in the electric, galvanic, and magnetic fluids, like that of general attraction, vary inversely as the squares of the distances of the bodies.

Boscovich has ingeniously represented the series of alternate attractions and repulsions supposed to be experienced by a particle of matter within the very small distances between that particle and another, by a curve consisting of several bends crossing and recrossing an axis in points at various distances from the origin, which may be supposed to be the place of the second particle above mentioned. The ordinates of this curve on one side of the axis represent attractions, and those on the other side repulsions; the places of crossing being supposed to be those at which the first particle would be at rest. Beyond the small distance above mentioned, this axis becomes an asymptote to the curve, and the ordinates of the curve here represent the general law of attraction (the inverse square of the distances). Near the origin of the axis the ordinates represent repulsions; and these ordinates constantly increase till they become infinite, so that a right line drawn through the place of the second particle, perpendicular to the axis, is an asymptote to this branch of the curve.

REQUEST, COURTS OF (sometimes called *Courts of Conscience*), were local tribunals, founded by Act of Parliament to facilitate the recovery of small debts from any inhabitant or trader in the district defined by the Act: they have been altogether superseded by the COUNTY COURTS.

REQUIEM (*Requies*, Lat., *rest*), the name of a mass sung in the Romish Church for the repose of the dead, beginning *Requiem æternam*, and in the Roman Catholic liturgy called *Missa pro Defunctis*.

REREDOS. [RETABLE.]

RESCUE, in Law ('rescous,' from the old French word *rescourser*, 'to recover'), is the unlawful and forcible setting at liberty a person or goods, in lawful custody. A rescue may be either a criminal offence or a civil injury, according to the circumstances under which it is effected. The character of the criminal offence is determined by the character of the offence committed by the person rescued. If, for instance, a party has rescued a traitor or a felon, he has committed the offence of treason or felony; but as the treason or felony of the person rescued cannot be assumed to have been committed until after his conviction and judgment, it is not proper to arraign the rescuer for such offences until after judgment of the principal offender. But the rescuer may be indicted for a misdemeanor before such judgment. For a rescue from lawful custody is in all cases a misdemeanor. Several statutes have, however, varied the character of this offence, and the punishment.

Previously to the abolition of arrest on mesne process, if a prisoner in custody of the sheriff on mesne process was rescued, the sheriff might make a return to that effect, which freed him from further responsibility; the rescuers being liable to an attachment for a contempt, and also to an action at suit of the plaintiff.

Where a party is arrested, or goods are taken upon a final process, the sheriff cannot return that there has been a rescue, and either he or the jailer is in all cases, except where the rescue is effected by the king's enemies, answerable in an action by the plaintiff. This liability is concurrent with the liability of the rescuers themselves, the plaintiff having the option to sue either the rescuers or the sheriff.

(Com., *Dig.*, 'Rescous;' Hale, *P. C.*; Hawk., *P. C.*; Russell, *On Crimes*; Matthews, *On Criminal Law*.)

RESERVOIRS. In engineering works the word *reservoir* is understood generally to apply to the large collections of water which are made for the purpose of feeding canals, or of supplying the head waters of a mill, or of supplying the water required for municipal services. The water, in almost all these cases, is obtained by storing the excess of the rain-fall (which would otherwise pass off from the surface of the land, by the streams or rivers, during the rainy seasons) in artificial ponds, provided with sluices, feeders, or main pipes, to conduct the water to the places where it is required. Under these circumstances the dimensions of reservoirs, and the modes of their construction, must admit of every imaginable variation; but the general principles connected with their formation may be briefly stated as follows.

The reservoirs for feeding canals, or inland navigation, may be made without much reference to the quality of the water to be stored in them; but those which are designed for the purpose of a town supply must be made in such places as to obviate any danger from the contamination of the water. It is customary that they should be formed, in either of these cases, if practicable, in the gorges of mountainous districts, where there might exist a large area of land having a natural fall towards the outlet of the gorge. Writers upon meteorology calculate that upon the average ⅓ of the total rain-fall of the whole year passes off by means of the superficial natural watercourses; that another ⅓ passes off by evaporation; and that the remaining ⅓ descends into the ground to feed the land springs and the wells. In mountainous districts, however, these proportions do not hold good; for, firstly, it happens that, as a general rule, the nucleus of mountain chains consists of dense impermeable rocks, which not only oppose the infiltration of water, but also from the steepness of their escarpments throw off the rain-fall in greater abundance than would be the case in more level districts. Secondly, on mountains the rain-fall is usually more abundant than it is on plains, and it is more evenly distributed over the year; so that the natural surface of the ground does not become so absorbent, nor does the evaporation from that surface take place with the same rapidity, as it would do in the low lands. It thus happens that the quantity of water, which may usually be calculated as being likely to find its way into a reservoir placed in a mountainous district, may be reckoned as being about one half of the total rain-fall; but the net quantity disposable will be often very inferior to the quantity thus originally impounded, because there must always be an active evaporation going on from the water surface, (which, moreover, will take place to the greatest extent when the water is most wanted) and there must always be a more or less active infiltration through the bed of the reservoir itself. As it will be necessary to discuss the effects of these conditions of evaporation and infiltration under the article WATER SUPPLY, on account of their influence upon gravitation water-works, it may suffice here to say that it is very rarely indeed that the engineer can depend upon commanding more than from ⅓ to ½ of the total quantity of the rain-fall of his drainage area; and that it is only exceptionally that he can attain the higher limit above quoted.

Another very important consideration will be found to affect the dimensions of reservoirs, which has only been cursorily noticed above, namely the distribution of the rain-fall over the year. In many cases it is known that rain does not fall for months together; and even in the Bagshot Heath district droughts of four and five months duration have taken place. A reservoir established in such a district must then contain; 1st, the total actual quantity required for the service it is intended to perform; and it is to be observed that during droughts the consumption of water must be nearly double that which would be required under normal circumstances, whilst the reservoir must be made large enough to supply the *largest* consumption, not the *average* one. 2nd, it must contain, in addition to this quantity, enough water to compensate for the evaporation and infiltration, and to secure the water from injurious chemical changes. In fact the water of large lakes even, unless constantly kept in motion by streams passing through them, is liable to become vapid and deficient in aeration; whilst pond waters, in dry, hot weather, become positively nauseous, unless their volume should be very great indeed; and vegetation, and the lower forms of animal life, develop themselves with singular activity under the same circumstances. Of course this latter consideration would not materially affect canal reservoirs, but it is an all important one in the case of gravitation water-works, and the singular story of the introduction of the *anacharis alsinastrum* into our canals, proves that it is expedient to watch the growth of aquatic plants even in canal reservoirs.

In all descriptions of reservoirs it is important that precautions should be taken to prevent the accumulation of alluvial matters of a nature to fill them up; and, in the case of water-works reservoirs, this is essentially necessary because the waters standing for a long time over them must contract impurities from those matters. The nature of the surface of the drainage area will regulate the nature of the precautions to be taken; for, if the soil should be one easily moved by the surface rills, it will be necessary to form depositing pits on the courses of the feeding streams; on hard limestone, slate, or plutonic formations, it may often only be necessary to prevent large boulders from being carried into the reservoir; and on peaty uplands, it will usually be found that the surface of the country will itself suffice to prevent the transport of much alluvial matter. The water obtained from peaty lands, it is to be observed, is not fit for the purposes of a municipal supply; and hitherto no satisfactory mode of removing the qualities communicated to the water by the peat has been discovered. For canal purposes peaty water is as good as any other, inasmuch as its colour and taste are of no importance for purposes of navigation; but either for irrigation, or for town supplies, such waters are inadmissible.

In selecting the position for a reservoir the most important conditions to be considered are, firstly, the nature of the bed; and secondly, the position of the retaining wall. The bed must not only, as said before, be of a nature not to communicate impurities to the water, but it must be for all practical purposes, impermeable. The value of a reservoir, in fact, depends on its power of storing, that is to say, of its holding water; but when the strata of which its bed is composed are so much fissured, or are of so permeable a nature as to allow the water to escape, it becomes necessary both to increase the original volume of the water stored, and to guard against the danger of the water's finding its way under the seat of the dam. The construction of the latter is, however, the most important part of the works required for the formation of a reservoir, for the depth of water against its face frequently is not less than 40, or even 70 feet, so that the pressure calculated to turn the reservoir over upon its outer edge, or to thrust it forward horizontally, is enormous; and the difficulties of construction increase precisely in proportion to the height and the length of the dam. Its position must therefore be selected in some portion of the gorge to be converted into a reservoir where the sides approach one another so as to contract the opening of the valley; the foot of the dam must be carried down far enough below the surface of the ground or of any subjacent permeable strata, to prevent the lateral passage of the water; its thickness must be made superior to that required to resist any possible dynamical effort it may be exposed to; the materials of which it is composed must be able to resist the passage of water; it must be made high enough to prevent waves, by whatever cause produced, from washing over its crown; and finally the overflows, bye washes, waste weirs and accessory structures (such as the sluices, draw-off pipes, &c.) must be made perfectly water tight, unless in the parts especially designed for the passage of the water. To secure the condition of the impermeability of the seat of a dam it is often necessary to carry the foundations as far below the surface as the dam itself rises, and instances of foundations fifty feet deep are by no means rare. Telford even recommended that when the strata on which a reservoir had to be formed were of a porous nature, the whole of the valley should be puddled; so great an importance did he attach to the necessity for opposing this dangerous action.

The dams of reservoirs are either formed of earthwork, or of masonry, or of a mixed system of earthwork and masonry. Local circumstances must guide the engineer in his selection of the precise nature of the materials he will employ; but the result of careful observations on the movements of large works of this description has led to the general recognition of the following practical rules for the thicknesses to be given. When masonry dams are used, it is found to be necessary to make the thickness of the wall, x, equal to the following proportions of the height of the dam above the surface of the bottom of the reservoir near its foot:

at the top . $x = h \times 0{\cdot}30$
in the middle $x = h \times 0{\cdot}50$
at the bottom $x = h \times 0{\cdot}70$

When earthwork is used the dam should be made from 15 to 16 feet wide at the top, with slopes of at least 1½ to 1 towards the water, and of 2½ to 1 on the dry side; the water side must be protected against the abrasion of the waves by stone pitching, and below the line of agitation its face must be carefully puddled. A wide puddle trench, or a thick wall of hydraulic masonry, should be carried up in the heart of the bank, and every precaution must be taken to resist the passage of the water through the various layers of the body of the work. As a general rule the materials of the bank should be deposited in layers of from 6 to 9 inches in thickness, and well and carefully rammed; care being taken to prevent anything like a perfect horizontality of bedding, by making occasional steps in the layers of earth. Similar precautions must be taken in the formation of masonry dams, and the layers, or horizontal beds must be stepped. It is also to be observed that there is a tendency in all long straight dams, of earth, or of masonry, exposed to the constant action of a great weight of water to assume in time the form of a catenary curve; and in order to resist this tendency it is customary to make earthwork dams segments of large circles in plan, with their convex side towards the water; and in masonry dams, it is usual to form strong counterforts on the down side, even when the same segmental horizontal outline, and the before-quoted thicknesses have been adopted. The usual rule is, it may here be added, to make the top of the dam about 5 feet above the maximum water level, in order to resist the action of the waves in the reservoir; a precaution which was proved, by the accident to the dam of the Croton reservoir, to be by no means exaggerated.

One of the most important accessory works of a reservoir is the bye wash, or waste weir; a portion of the enclosure over which any water is allowed to pass after the reservoir itself is filled to its maximum water line. The length of the bye wash must be made sufficient to carry off in a thin stream, the surplus products of the most violent storms, or of the most continuous winter's rains; and it must be made in such wise that the water flowing over it should not affect the stability of the dam, either by the cataract of the falling water, or by the velocity of the stream flowing from the foot of the bye wash. For the service of canals, or of town distribution, the water is drawn off by a series of sluice-gates, provided with the necessary contrivances to regulate the velocity of flow in the distributing channels; and it may be stated that, for a town distribution, the variable head upon the main pipes which is usually admitted, does not exceed 13 feet; and that in all cases it is desirable that the efflux of the water through the feeders, or the mains, should take place with as great regularity as it is possible to attain.

Some idea of the importance of the reservoirs formed for the supply of canals and town distributions may be derived from the following notes upon some of the most remarkable works of this description. Thus the Fountain Reservoir of the Croton aqueduct covers 400 acres, and has a depth at the dam of 38 feet: the Manchester Corporation Waterworks cover an area of above 408 acres, and have an average depth of 35 feet 6 inches, or they have a storeage capacity of 584,866,716 cubic feet; the Liverpool reservoirs have a storeage capacity of about 3,156,000,000 gallons; the Yan Yean reservoirs in Victoria, have an area of 1303 acres, and a storeage capacity of 6,400,000,000 gallons. The Canal du Midi, of France, has at Gros Bois, a reservoir of 300,510,000 cubic feet capacity, with a head of water at the dam of 69 feet 6 inches; the reservoir of the Nantes to Brest canal has a capacity of about 262,395,000 cubic feet, and a head of 38 feet; the reservoir of St. Fériol, on the canal du Midi, has a capacity of 223,090,000 cubic feet, and a head of 105 feet. The Birmingham canal has a reservoir of 80 acres area, with a depth of 45 feet at the head; the reservoir of the Union canal of Philadelphia, is not less than 780 acres in area, by an extreme depth of 40 feet, and it has a capacity of 572,000,000 cubic feet; on the Rideau canal of Canada, there is a dam 70 feet high; the Turton and Entwystle reservoir, in Lancashire, is of 100,000,000 cubic feet in capacity, &c. In England, it seems that the usual ratio of the storeage capacity to the area of gathering ground is from 30 to 40 thousand cubic feet per acre; and it is found practically that the maximum quantity stored never exceeds 15 inches over the area of the gathering grounds, in the most favourably inclined and impermeable districts; nor does it ever exceed 12 inches in flat retentive ones. The cost of forming large reservoirs has rarely, if ever, fallen short of 450*l.* to 500*l.* per million cubic feet of the storeage capacity, leaving out of account the accessory works, or the purchase of the land. A very important element in the cost of all such works is to be found in the compensation to be given to the parties who were formerly entitled to the water privileges existing in the district; but it is not possible to discover any general rule applicable to the countless variety of cases of this description. Some remarks on the subject will be found under WATER MILLS.

There is an important distinction to be made between the various kinds of reservoirs used upon town distributions, which may be mentioned here, though the discussion of the principles of their construction must be referred to WATER SUPPLY. The distinction in question is the one between the open storeage reservoirs, and the covered reservoirs, from whence the waters are distributed, generally after filtration. The latter are extremely costly structures, and are, therefore, rarely made larger than would be required for a four or a seven days' supply at the maximum; whilst the storeage reservoirs are made large enough to hold a quantity equal, when the rain-fall is about 60 inches per annum, to about 120 days' consumption; when it is about 48 inches, to about 140 days' consumption; and when it is about 22 inches (which is the case in the eastern parts of England), to about 200 days' consumption.

It may be interesting, archæologically, to add that some of the most extraordinary mountain reservoirs in Europe are those which were constructed by the Moors of Spain; that the Egyptians under the Pharaohs had executed some wonderful works for the purpose of storing the inundation waters of the Nile; that the native rulers and the Mohammedan conquerors of India vied with one another in the construction of the colossal tanks of that country; and that even the Aztecs had adopted a peculiar system of aguadas, or underground reservoirs, for the purpose of storing the copious but partial rains of their country. The Moors and the Egyptians seem to have used the water they stored principally for the purpose of irrigation. The Greeks and the Romans supplied their towns with water from springs and rivers, and very rarely attempted to execute irrigation works, so that there are no authentic records of the formation of artificial storeage reservoirs by either of those nations. One of the most ancient works of this description whose history can be identified in modern times is the reservoir of St. Fériol, on the Canal du Midi; and nearly contemporaneously with it the system of catchwater ponds, which supply partially the fountains of Versailles, was executed by the orders of Louis XIV.

RESIDUAL, an expression which gives the remainder of a subtraction, as $a - b$.

RESIDUARY LEGATEE. [LEGATEE.]

RESIGNATION. [BENEFICE.]

RESIN. [TURPENTINE.]

RESINEIN. [TURPENTINE.]

RESINS, a large class of substances, existing chiefly in the vegetable kingdom, and of which common resin, rosin, or colophony, is the type. They are generally obtained by incising the bark of trees; *oleo-resin*, or a mixture of a volatile oil and resin, then exudes, and gradually hardens. It is possible that the resins do not exist as such in plants, but that they are produced by the oxidation of essential oils.

The chief properties of resins are: insolubility in water; non-volatility; solubility in alcohol, ether, benzole, essential oils, and by the aid of heat in fixed oils; are insulators of electricity; become negatively electric by friction; fuse when heated; and, in contact with air, burn with a bright, but very smoky, flame.

But little is known of the constitution of resins. Constantly, but slowly, absorbing oxygen, with or without evolution of carbonic acid or water, or both, it is almost impossible to obtain them in anything like a definite state. Again, with one or two exceptions, they do not crystallise, and this greatly increases the difficulty of determining their individuality. Some—such as santonin, eugenin, gamboge, cubebin, myrrh, and chrysophanic acid—seem to be produced by the simple replacement of a number of equivalents of oxygen for an equal number of equivalents of the hydrogen in the essential oil. Others, for example, styracin, anime, red resin of rhubarb, mastic, amber, elemi, and aloetin; not only take up oxygen in the place of hydrogen, but also assimilate water. Many are probably mere oxides of the volatile oils; some we know to be simply hydrates. As yet, the resins have not been artificially formed from the pure essential oils: could this be accomplished, an important insight into their constitution would, no doubt, be obtained.

The solutions of several of the resins in alcohol redden litmus-paper, indicating that they are acid bodies. Such resins combine with alkalies to form soaps, differing but little from ordinary soaps. Common rosin, for example, contains *sylvic acid*, which crystallises in prisms; *pimaric acid*, which is obscurely crystalline; and *pinic acid*, which is amorphous. These acids, as well as many other solid and liquid bodies existing in or obtained from resins, will be found described somewhat more in detail under TURPENTINE.

Many of the resins are used in medicine; several have considerable commercial value, being used for the preparation of varnishes by dissolving in turpentine, wood naphtha, or spirit of wine.

The more important resins are treated of in this division of the ENGLISH CYCLOPÆDIA under their respective names, or in the NATURAL HISTORY DIVISION either individually or under the name of the plant from which they are obtained.

Gum-resins, as the name implies, are mixtures of GUM and resin.

For *Icicane*, and resin of icica, see TURPENTINE.

The resins of commerce are in some cases natural exudations, while others are obtained from vegetable compounds by the action of alcohol. They are for the most part brittle, tasteless or insipid, and fusible at a moderate heat; they seldom have any smell; they generally burn with a strong yellow flame, emitting a large quantity of smoke.

The ordinary resin of the shops is *colophony*, obtained as a residue after the distillation of oil or spirit of turpentine from common turpentine. The *black* resin is the cooled brittle mass in the state in which it leaves the still; whereas the yellow resin is the black modified by the action of water. *Resin-oil* is made in London, Liverpool, Bristol, Hull, and Glasgow, as an ingredient in lubricating grease for railway axles and for the bearings of heavy machinery. It is also used in France as an ingredient in printers' ink, thereby giving the unpleasant odour which is often observable in newly-printed French newspapers. Most of the common resin comes from North America, to the extent of 20,000 tons or more annually. *Resin-gas* is largely made in America; but in England it does not successfully compete with coal-gas. The chief uses of the various resins in England are for varnish, lacquer, sealing-wax, and dyeing.

RESISTANCE is a power by which motion, or a tendency to motion, in any body is impeded or prevented. When a weight or pressure acts upon a beam or bar in any direction, the tenacity by which the particles of such material oppose that action constitutes a resistance of one kind. [Materials, Strength of.] Again, when a body is made to move on another, the inequalities of the surfaces of both create a resistance of a different kind. [Friction.] When a body moves in a fluid, the inertia of the fluid particles displaced by it produces a third kind of resistance.

This last branch of the subject of resistances has already been in part considered under Hydrodynamics. In that article there is given a general expression for the measure of the resistance made by a fluid against a plane surface which is either perpendicular or inclined to the direction of the motion, together with a few results of experiments on the resistances experienced by bodies of various forms and lengths in moving through water. The relations between spaces and times in the vertical ascent and descent of bodies when acted on by gravity and resisted by a fluid, are given in the article Projectiles, Theory of; and, for the pressure against a cannon-ball moving in air, see the article Gunnery.

In investigating the resistances of fluids against bodies moving in them, it is customary in elementary writings, for the sake of simplicity, to consider the particles of fluid as unconnected with each other by contact or by any law of attraction, so that, when struck, their reactions may be considered as taking place perpendicularly to the striking surface of the moving body, whatever be the position of this surface with respect to the direction of the body's motion, and after the impact their action is supposed to cease. Such are called discontinuous fluids, and in these the motion produced in the particles by the collision is the measure of the resistance. Newton shows ('Principia,' lib. ii., prop. 35) what would be the resistance experienced by a cylinder moving in the direction of its axis in a discontinuous fluid; the cylinder and particles of fluid being elastic, so that the latter on being struck are reflected back with a velocity double the velocity of the cylinder; and he explains that, if the particles of fluid are not reflected, but are moved forward by the cylinder with a velocity equal to its own, the resistance is but half the former. But this hypothesis is far from being conformable to the constitution of fluid bodies in nature, the particles of these being connected by mutual actions. The elastic fluids, as air, at any place in the atmosphere are always in a state of compression from the weight of the column vertically above that place; and the particles of non-elastic fluids, as water, exert in every direction pressures which depend upon the distances of the particles below the surfaces of the fluid in the vessel, river, or ocean. In passing through a fluid of this kind (called a continuous fluid) a body strikes only the fluid particles which are nearest to it; these strike those beyond, and so on; and Newton proves (lib. ii., prop. 35, schol.) that in this case the resistance to a cylinder is only half the last-mentioned resistance, or one-fourth of the first.

In all these resistances however it is supposed that the particles on being struck are repelled perpendicularly to the front of the moving body; but, in fact, the particles of the fluid are in part repelled from the front in oblique directions, and, on account of the compressed state of the surrounding fluid, these particles not being able immediately to escape laterally, there is produced in front more or less condensation, and consequently an increase of resistance. The pressure of the fluid against the sides of the moving body creates also a resistance from friction; and when the velocity is very great, the fluid not falling towards the hinder part of the body so fast as the latter moves, the pressure there which would serve to counterbalance the resistance in front, is in part or wholly removed. On these accounts it is that military projectiles are subject to such vast retarding forces. It is computed that a 24-pounder ball experiences a resistance equal to 800 lbs. when its velocity is equal to 2000 feet per second. Like effects take place in the movements of boats and ships; when the velocity is great, the water accumulates in front, and flowing off from thence obliquely, it carries away some from the sides, and, causing the surface of that which is near the stern to be rather lower than the general level, it there produces a diminution of pressure, while there is an excess in front on account of the accumulation.

In order to find the pressure of a fluid against a body which is terminated in front by a curve surface, an expression must be obtained (by means of the equation of the surface) for the area of an elementary portion of that surface, and this must be multiplied by the cube of the sine of its inclination to the line of motion. The product being multiplied by $\frac{v^2D}{2g}$ [Hydrodynamics], and the whole integrated between the proper limits, the result will express the required resistance.

Again, in investigating the motion of a body on an inclined plane when resisted by friction and the pressure of the atmosphere, the general equation of motion $\frac{d^2s}{dt^2}=g-a\frac{ds^2}{dt^2}$ may be employed. Here s is the space described in the time t, $\frac{ds}{dt}$ is the velocity acquired in the same time, and $\frac{d^2s}{dt^2}$ is the differential expression for accelerative or retardative force. If the body were to descend vertically, g, the force of gravity (= 32·17 feet), would alone be the force producing the motion; and the equation, being integrated, would give the relation between the spaces described and the times of description when the body descends or ascends in a resisting medium. In the first of these cases g should be positive, and in the second negative. In order to adapt the equation to the descent of a body on an inclined plane, let θ be the inclination of the plane to the horizon; then $g \sin. \theta$ would represent the accelerative force on the plane if there were no friction. But since friction is proportional to the pressure ($=g \cos. \theta$) on the plane, and is independent of the velocity, let h be put for the coefficient of friction and represent a fractional part of the pressure; then we shall have $hg \cos. \theta$ for the retardation produced by friction. a is the coefficient of the resistance due to the pressure of the atmosphere; it depends on the form and magnitude of the moving body, and not on its weight; and the resistance is supposed to be proportional to the square of the velocity. Thus the above equation becomes

$$\frac{d^2s}{dt^2}=g \sin \theta - hg \cos \theta - a\frac{ds^2}{dt^2};$$

or, since the two first terms of the second member are constant, representing them by A, it becomes $\frac{d^2s}{dt^2}=\text{A}-a\frac{ds^2}{dt^2}$. Integrating this equation by successive approximations, or otherwise, we obtain in terms of t the values of $\frac{ds}{dt}$ (the velocity) and of s (the distance on the plane), either when the body sets out from a state of rest, or when it sets out with any given initial velocity. From these values, by means of the data obtained from good experiments, the values of h and a might be found; and thus the effects of friction might be obtained separately from those which are due to the resistance of the air.

The formulæ which are now generally received as expressing the resistances to which waggons moving upon railways are exposed are as follows:—They are of two classes; the one normal, and the other accidental; the one susceptible of *à priori* calculation, the other depending upon the state of the road, the action of the wind, &c., or upon conditions of an essentially variable nature. Of the normal causes of resistance, there are three kinds: 1, the friction of the axles in the boxes; 2, the friction of the wheels upon the rails; and 3, the resistance of the air, supposed to be in a state of repose, to the advance of the train. The level of the surface of the roadway naturally affects the numerical calculations of the various conditions thus specified; but, as was before said (under Railway), the introduction of the expansion gear into locomotive machinery has so modified the powers of that class of engine, that the importance of the precise value of the resistances to be overcome has of late been materially diminished. With an engine whose powers can be increased at will, and almost instantaneously, variable resistances are really matters of very little moment. The formulæ for this class of resistance are extracted from Perdonnet's 'Traité Elémentaire des Chemins de Fer.'

Taking into account, firstly, the case of a waggon moving in plain and on a dead level, it is evident that the horizontal movement must produce a friction of the bearing surface of the axle-boxes upon the axles themselves, which will be proportional to the pressure (or to the weight of the carriage, minus that of the wheels and axles), and will vary with the state of the bearing surfaces, but independently of their own state. If, then, the pressure upon the axle-boxes be represented by P, and the coefficient of friction by f (it will, in fact, be regulated by the nature of the bearing surfaces, their smoothness, and the nature of the lubricating material), the friction of the boxes on the axles will be represented by fP. Then, calling R the radius of the wheels, and r the radius of the bearing of the axle, every revolution of the wheels will cause the waggon to advance a distance of $2\pi\text{R}$, and every point of the bearing a distance of $2\pi r$; so that whilst the waggon advances through a distance = 1, the bearings of the axles will have slid over a surface $\frac{2\pi r}{2\pi\text{R}}=\frac{r}{\text{R}}$. The value of the friction of the bearings will then be, for the same distance traversed, $f\text{P}\frac{r}{\text{R}}$.

The friction of the wheels against the rails is a friction of the kind known as a rolling friction, and as such it is generally considered to be proportional to the pressure, and variable according to the nature of the surfaces in contact, but independent of the area of those surfaces, and of the speed of the motion. Or, calling p the weight of the wheels and axles, the total pressure or weight will be $\text{P}+p$, and f' the coefficient of friction, the expression of this description of friction will then become $f'(\text{P}+p)$. Strictly speaking, the value of f' would depend on the size of the wheels; but as, practically, the wheels of railway carriages are of the same diameter, f' may be considered to be a constant quantity.

When a body moves in a discontinuous fluid in repose, the resistance it meets with is proportional to the square of the velocity; to the area of the section of the body moved, taken normally to the direction of the movement: it is less in proportion to the length of that body in the direction of the movement; and if two surfaces, covered one by the other, move in the same direction, the resistance of the covered face will be equal to a fraction of the face immediately exposed to the air; and the smaller the interval between the two faces, the less will be the fraction in question. If, then, Q be called the resistance of the air sought, A = the area of the exposed end, V = the velocity of motion, ϵ = a co-efficient depending upon the length of the train, and θ = a constant co-efficient to represent the resistance caused by the intervals, the resistance of the air will be represented by the formula—

$$Q = \theta \epsilon A V^2.$$

It thence follows that the sum of the calculable resistances to be overcome when a train moves in a straight line, on a level road, may be represented (calling the resistance T) by the formula,

$$T = f P \frac{r}{R} + f' (P + p) + \theta \epsilon A V^2.$$

When the train moves upon an incline forming with the horizon an angle a, the gravity of the train is decomposed into two portions, one of which is perpendicular to the plane of the rails, and the other acts in a direction parallel to that plane, and tends to draw the train downwards; so that in pulling a train up an incline, the locomotive must exercise a power, not only able to overcome the friction, but also to overcome this effort of gravity in the direction parallel to the surface of the incline. The latter force, as is well known, is equal to $(P + p) \sin a$; the pressure of the bearings of the boxes upon the axles is equal to $P \cos a$; and the pressure of the wheels normally to the rails is equal to $(P + p) \cos a$. The force, then, which the locomotive must exercise upon a waggon in order to allow the latter to retain the velocity it had at any particular moment, under the conditions supposed, must be

$$f P \cos a \frac{r}{R} + f' (P + p) \cos a + \theta \epsilon A V^2 + (P + p) \sin a.$$

As the inclines upon railways are generally such that we may consider $\cos a = 1$, and that $\sin a = \mathrm{tg}\, a$, we may consider that the force exercised may, practically, be represented by the formula,

$$f P \frac{r}{R} = f' (P + p) + \theta \epsilon A V^2 + (P + p)\, \mathrm{tg}\, a.$$

The resistances a waggon encounters on a curve are of a complicated nature, and in a railway waggon they become more than usually so, from the fact that the wheels are fixed on the axles. Calling a the half width of the way, and ρ the mean radius of the curve, if the centre of the waggon travel over a space = 1, the interior wheels will travel $\frac{\rho - a}{\rho}$, and the exterior wheels $\frac{\rho + a}{\rho}$; so that the slip of each of them will be $\frac{a}{\rho}$. Now the wheels exercise a pressure $= P + p$, and if we represent the co-efficient of friction by f'', the expression of the resistance created by the fixity of the wheels will become $f'' (P + p) \frac{a}{p}$ for every unity of distance. But there is another resistance developed on a curve from the two axles of a carriage being fixed to its frame; for whilst the centre of the carriage traverses a circle described by the radius O (the mean radius of the curve), the respective points of contact of the axles describe a circumference around the centre G of the rectangle formed by the points of contact of the wheels and of the rails. The radius corresponding to these points of contact is $GA = \sqrt{a^2 + b^2}$, b representing the half distance of the two axles, and a the half distance of the two points of contact of the wheels on the same axle. The slip of the wheels, whilst the waggon makes a revolution round O, becomes then $f'' (P + p)\, 2 \pi \sqrt{a^2 + b^2}$. In the same space of time, the distance traversed by the waggon $= 2 \pi \rho$; so that the resistance caused by the wheels being fixed on their axles, and by the parallelism of those axles themselves, is represented by the formula,

$$f'' (P + p) \frac{2 \pi \sqrt{a^2 + b^2}}{2 \pi \rho} = f'' (P + p) \frac{\sqrt{a^2 + b^2}}{\rho}.$$

There is a third force developed during the curvilinear movement of a waggon arising from the pressure of the rims of the wheels upon the outer rail, whose expression is $\frac{P + p}{g} \cdot \frac{V^2}{g}$; in which g represents the accelerating force of gravity, which is in our latitude $= 32\frac{1}{6}$ feet. This pressure gives rise to a friction, $f''' \frac{P + p}{g} \frac{V^2}{\rho}$, in which f''' represents the co-efficient of the friction created by the pressure of the rims of the wheels upon the inner surface of the outer rail. But in addition to this there is a friction exercised by the surface of the rim in its motion along the inner edge of the rails, and the resistance thus developed by the friction due to the centrifugal force, for every unity of the advance of the waggon, is $f''' \frac{P + p}{g} \frac{V^2}{\rho} \frac{\sqrt{2 R h + h^2}}{R}$; in which R = the radius of the inner edge of the rim of the wheel, and h = the depth of that rim. The additional resistance thus created by the passage of a train over a curve is, then, represented by—

$$f'' (P + p) \frac{\sqrt{a^2 + b^2}}{\rho} + f''' \frac{P + p}{g} \frac{\surd^2}{\rho} \frac{\sqrt{3 R h + h^2}}{R}.$$

The total effort which the locomotive must exercise in order to retain the velocity it previously had, must, during the unity of the distance traversed, be equal to the sum of the resistances above stated; and it is therefore represented by the formula

$$T = f P \frac{r}{R} + f' (P + p) + \theta \epsilon A V^2 + (P + p)\, \mathrm{tg}\, a + f'' (P + p) \frac{\sqrt{a^2 + b^2}}{\rho}$$
$$+ f''' \frac{P + p}{g} \frac{V^2}{\rho} \frac{\sqrt{2 R h + h^2}}{R}.$$

In Perdonnet's 'Traité Elémentaire,' in Wood's 'Treatise on Railways,' in the second edition of M. de Pambour's 'Traité des Machines Locomotives,' &c., the various experiments by which the values of the various co-efficients in the above formulæ have been ascertained, are discussed at length. It may suffice here to say that generally speaking the values assigned by Coulomb to the co-efficients f, f'', are considered still to apply, though they are evidently in excess of the actual values as they have been indicated by experiments on railway trains; for Mr. Wood found that the total resistance of waggons of the old model travelling, at small velocities, upon a level straight line, was 0·00475 $(P + p)$, and De Pambour found it to be only 0·0026 $(P + p)$. Messrs. Gouin and Lechatellier found, by direct experiment with Morin's dynamometre, that the resistance from this cause was, at speeds varying between 15 to 25 miles per hour, equal to 0·003 to 0·0045 $(P + p)$; at speeds between 25 and 38 miles, it was = 0·0045 to 0·0085 $(P + p)$; and for speeds between 50 and 60 miles, it was = 0·012 to 0·015 $(P + p)$ On the average it may be taken that these resistances amount to 0·004 $(P + p)$.

De Pambour gives the value of $\theta = 0{\cdot}004823$, and that of $\epsilon = 1{\cdot}17$ for a cubical body, = 1·07 for a train of five carriages, = 1·05 for a train of fifteen carriages, and = 1·04 for a train of twenty-five carriages; but the learned author seems to consider the truest value of ϵ to be = 1·13. It is generally considered that the value of $f'' = 0{\cdot}16$; the value of f''' has not been ascertained by direct experiment, but it is known to be considerably greater than f''.

The practical conclusions drawn from the examination of these formulæ are: 1. The resistance is diminished by diminishing the diameter of the axles, and increasing that of the wheels. 2. It is desirable to diminish the weight of the carriages as far as may be consistent with safety. 3. The resistance in traversing a curve is increased in proportion as the radius is decreased. 4. The useful effect of locomotives is materially affected by their rate of motion, and economically there are serious objections to high rates of speed.

The experiments of Messrs. Gouin and Chatellier show also that a great portion of the resistance of a train arises from the frictions produced by the frame of the engine, and the frictions of its machinery. They found that, in fact, when the resistance of the whole train was equal to 0·0105 per ton, that of the carriages alone was 0·00625; that created by the frictions of the machinery alone, without reference to the load, was 0·0025; and the resistance created in the machinery by the pressure of the steam, was 0·00175. The speed in this case was about 28 miles per hour, and the experiments were tried on an incline of 1 in 125; the weight of the train was 60 tons, and the weather quite calm. Finally, it may be stated that it is usually considered that taking into account both the variable and the constant resistances to be encountered on railways the force required to ensure the traction at speeds of 20 miles an hour is equal to $\frac{1}{200}$ th of the load; and that if the speed should exceed 30 miles an hour it becomes $\frac{1}{100}$th of the quantity.

The method of finding the resistance which an engine opposes to the effort made by the steam to put it in motion, is as follows:—Multiply the area of one of the two equal pistons in square inches by the pressure of the steam on a square inch of the piston in each cylinder, when that pressure is just sufficient to cause the engine to move; the product is the pressure on each piston. Then, since the piston makes two strokes while the wheel of the engine turns once round, the velocity of the piston is to that of the engine as twice the length of the stroke is to the circumference of the wheel; and, the resistances being inversely proportional to the velocities, we have—

circumf. of wheel : twice the length of the stroke : : pressure on both pistons : the resistance, or inertia, of the engine.

But the resistance increases with the load which the engine has to draw; and, in order to determine it when attached to a train, the above proportion may be used; but the pressure on the pistons, instead of being found as before, must be taken when the engine and train are observed to have a uniform motion. Then the fourth term of the proportion being diminished by the known resistance of the train, will give the resistance of the engine alone.

From the experiments of Mr. Telford, the following values of the resistances experienced by loaded carriages on level roads have been determined. On a good pavement the resistance is $\frac{1}{70}$ of the weight of the carriage and load; on a broken surface of old flint, $\frac{1}{35}$; on gravel, $\frac{1}{13}$; and on a well-constructed railway, from $\frac{1}{300}$ to $\frac{1}{250}$.

By experiments made on the force (of traction) required to give motion to vessels on canals, it is found that the resistance varies nearly as the cube of the velocity; and this great deviation from the general law of resistances is probably caused by the reaction of the sides of the canal against the water displaced by the vessel. It deserves, however, to be mentioned, that when the velocity of the vessel is considerable, the resistance has been found to experience some diminution, perhaps on account of the water momentarily displaced, from its inability to escape laterally, becoming condensed, and thus giving superior buoyancy to the vessel, the immersed part being less, the pressure of the wate against the front will also be less.

Mr. Barlow observes that, with small velocities, the force of traction on canals is less than on railways; and when the velocity is equal to four miles per hour, the forces are equal. Beyond this velocity the advantage is in favour of the railway.

RESISTANCE OF MATERIALS. When solid bodies are exposed to the action of external forces, they are capable of resisting those forces by reason of the cohesion or of the elasticity they may possess, until their own powers are exceeded, when the particles of which the solid body in question is composed begin firstly to change their respective positions, and finally separate from one another. Within certain limits, the solid bodies in question are susceptible of resuming their original form after their particles have begun thus to change their positions (under conditions depending upon the nature of the external force) when the force is withdrawn; and it is according to the energy and the mode of exhibition of this power that bodies are ranged in the classes of elastic or non-elastic bodies, of highly elastic or perfectly elastic bodies. When the force is exercised in a direction parallel to the longitudinal axis of the body in a manner to pull or to extend it, the force is said to be one of *traction*, or extension; when it acts in the direction able to bind the particles of the body into closer contact, it is said to be an effort of *compression;* when it acts in a direction able to cause one part of the body to slide over the other,—or, in other words, to split it,—the force is said to produce an effort of *detrusion;* and when it acts so as to twist the particles or fibres of the material one over the other, the effort is said to be one of *torsion*. The terms *elastic*, *highly elastic*, and *non-elastic* bodies sufficiently explain themselves; but it may be desirable to add that bodies are said to be *perfectly elastic* when they resist, with equal energy, efforts of compression and of extension. The best wrought iron is an illustration of this property; but in the case of good cast iron, the resistance to compression is equal to nearly 6¼ times the resistance to extension: the former is nearly a perfectly elastic body, the latter is only imperfectly such. It was formerly considered that the compression of solid bodies took place equally, or, in the words of Hooke, that *ut tensio, sic vis;* but more recent experiments have shown that, beyond certain limits, the compression and extension take place with a greater degree of rapidity than would be proportional to the increase of the effort. The limits of equable resistance thus alluded to correspond with the range of the unimpaired elastic powers of the body; for if the effort should be such as to cause the body to compress or to extend with an accelerated velocity, the original dimensions and form will not be reassumed when the effort is withdrawn. Bodies so affected are said to have had their permanent elasticity interfered with; or their elasticity has been changed, so as to produce either a permanent elongation, contraction, or flexure, as the case may be.

There is a very important consideration which must always be borne in mind in determining the effort to be applied to any body, namely, that the length of time during which it is so applied has a material influence upon the resistance; or, in other words, bodies will resist instantaneous efforts of far greater value than they can resist permanently, without alteration in their elasticity. It therefore becomes a matter of necessary precaution (in all building or mechanical operations), to keep the forces to which the various materials are exposed considerably within the limits of what would be able to produce instantaneous changes of their natural elastic states; and this is the more necessary because the materials alluded to are, in practice, subject to shocks, jars, or accidental efforts, which may be of a serious nature.

Modulus of Elasticity.—If a prismatic, or cylindrical body of a given length, L, and an area A, be exposed to an effort of longitudinal traction in the direction of its axis P, it would extend under this action by a quantity we may call l; and if this quantity should be proportional to the total length, in such a manner as that $\frac{l}{L}$ should be a constant quantity, it may be represented by i, and will represent the elongation for every unit of length. Now, so long as this quantity does not exceed the limits of the perfect elasticity of the material, i increases proportionally to the load and the area, or to the ratio $\frac{P}{A}$; so that in fact $\frac{P}{Ai}$ is a constant quantity, which is called the *co-efficient*, or *modulus of elasticity*, and is usually expressed by E. If then, the transverse section were equal to the unity of surface, and the elongation i, for every unit of length, were equal to that unit of length, $A i = 1$, and $P = E$ would be the effort supported by the unity of surface, and able to produce for the unity of length an elastic elongation equal to that unity. The same remarks will apply to efforts of compression, and it is generally admitted that the co-efficient of elasticity has the same value in the two cases, although in certain granular bodies this law does not appear always to hold. As the relation $P = A E i$ becomes $P = E i$ and from thence $E = \frac{P}{i}$, when the load P is supported by every unity of the section A, it is easy to determine the value of E for every such unity of section, and thence to calculate the value of the load able to produce a given elongation of the body presenting that section, or to calculate the elongation produced by a given load.

Extension and compression.—A very great number of observations have been made for the purpose of ascertaining, experimentally, the laws which regulate the extension of solid bodies, the results of which may be briefly stated as follows. The load which is capable of producing rupture by extension, is directly proportional to the transverse section of the body considered; and the load has no reference to the length, provided the material be homogeneous, and the weight of the body be taken into account. The substances which have the highest co-efficient of elasticity, are those which resist rupture by extension in the most energetic manner; that is to say, they are the most tenacious. The temperature of the bodies considered must be taken into consideration; for the expansion produced by an increase of temperature in many substances acts in such a manner as to produce a longitudinal extension, whereas in others it produces a change in volume; and this remark may be extended also to the changes which follow upon any alteration in the molecular structure of a body; because, in the first place, every new crystalline arrangement is liable to produce some change in the volume of the substance, and in the second, the relative positions of the axes of the crystals may, and often do, singularly affect the powers of resistance to extension. In a great number of the materials used in the arts the resistances to extension and to compression are nearly equal; but there are cases (as for instance, building stones and cast iron) in which there are marked differences in these respective powers.

As a general rule, it is more important in the arts to know the limits of the resistance of the substances employed to efforts of compression, and it thus happens that the majority of the experiments, made upon the physical properties of those bodies, have been made with a view to the solution of that class of investigations. The law before stated, as applying to the resistance to extension, sensibly holds with respect to compression, and it is expressed by the formula $N = A R$, in which $N =$ the total effort exercised normally to the direction of the base, $A =$ the sectional area of the prism, and $R =$ the resistance for every unity of the section. When, however, the bodies pass certain lengths, compared with the dimensions of their sides, the resistances to compression cease to follow the ordinary law, and it becomes necessary to divide the theoretical results, obtained by the application of the tables of resistance, by a co-efficient varying with the proportionate length of the prism to the diameter of the polygon circumscribed upon its base. Thus, when the diameter of the polygon is in a lesser ration than 1 to the following tabular numbers, representing the height, the co-efficient becomes, in each case, as under:

Ratio 1 . . .	10	15	20	25	30	35	42	46	50
Co-efficient . .	1	1·2	1·6	2	2·8	4	6	8	10

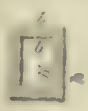
Again, the form of the body experimented upon, and the relative positions of its molecules, have an important influence on its resistance, for Vicat has shown ('Annales des Ponts et Chaussées,' 1833) that the resistance of a cylinder of stone to compression, in a direction at right angles to its bedding, is rather greater in proportion than that of the circumscribed square; a cylinder laid flat crushes under a weight which does not exceed $\frac{1}{3}$ of the one required to crush it when loaded on end; and the inscribed sphere will crush under $\frac{1}{4}$ of the load of the cylinder. Compound substances were found to crush more readily than homogeneous ones; that is to say, that cubes of stone built up of several pieces were found to crush more easily than monoliths did; but the general conditions of their resistance to compression were, after due allowance for this law, precisely analogous to those of solid bodies. In fact, in large masses of masonry, the resistance to efforts of compression is regulated by the resistance of their weakest parts, that is to say, by the resistance of the mortar used; and if it were required to calculate within safe limits the condition of the stability of a lofty pier, it would also be necessary to apply the co-efficient for the relative heights and bases just quoted. Vicat observes that in many cases loads, which for as much as 95 days were not able to produce any perceptible effect upon the bodies exposed to their compressive action, were able ultimately to destroy them; and he thence inferred that it was not safe to employ any materials, under efforts of permanent compression exceeding $\frac{2}{10}$ of the effort required to produce instantaneous rupture. In the case of substances possessing very imperfect elasticity a diminution of volume may frequently be produced by an effort of compression, which would not be recovered if that effort were withdrawn, even though the substance had not begun to disintegrate, nor its molecules had lost their cohesion. The clays and loams, so frequently met with in foundation works, are exposed to this peculiar action; and it requires to be taken seriously into account in building operations. Water is one of the imperfectly elastic bodies, but it resists compression with very great energy.

Temperature has a decided influence upon the powers of resistance of bodies to efforts of compression. For an increase of temperature, beyond the atmospheric average, diminishes in a gradually accelerating ratio the solidity of the bodies, whilst a decrease of temperature, below the freezing point, by affecting the powers of cohesion (or in common phrase by its rendering the bodies more brittle), causes the bodies to break up more rapidly. In materials obtained from stratified deposits, such as the decidedly laminated building stones, &c., Vicat found that the resistance to compression was much greater when the effort was applied in a direction perpendicular to the bedding, than when it was applied in a direction parallel to the beds; and in fibrous materials the resistance to efforts, either of extension or of compression, is the greatest when those efforts are applied in the direction of the fibres. In this last-named class of materials it is especially necessary to preserve them from flexure in their length; and thence also the necessity for observing the proportions before stated between the various conditions of base, height, and load. As it has been ascertained, theoretically and experimentally, that when the mass of a body is arranged in the form of a hollow body, the resistance is nearly doubled, (when the thickness of the cylinder is made about $\frac{3}{10}$ of the diameter,) it becomes an additional reason for using hollow columns of metal to support heavy loads, because, in the first place, the powers of resistance to compression are increased, and, in the second, there is less danger of flexure, when the diameter of the body is thus made as large as possible.

In the works of Tredgold, Hodgkinson, Tate, Barlow, Moseley, Willis, Whewell, Morin, Navier, Prony, Bresse, Claudel, Bourdais, Daguin, Jamin, &c., the various conditions of the resistance of solid bodies, and of the forms of greatest resistance, are discussed in great detail; and the reader is referred to them, should he require to examine any complicated problem of this description. It may suffice here to say that the condition most commonly occurring in practice is, when a rectangular beam is exposed to a load acting either longitudinally, or transversally, to its axis. In the former case the whole action is either of compression or of extension, as the case may be, and in addition to what has been before stated, it is only necessary to observe that it is essential, in order that the action should be uniform, that the load should be brought to bear evenly over the whole area. When beams are, however, exposed to efforts acting transversally to their axes, the laws of their resistance become more complicated, for the deflections produced cause some of the fibres to pass into a state of tension, whilst some of the others are compressed, and some of them remain in a neutral state, as long as the limits of elasticity of the extended or compressed fibres are not exceeded. The modes of loading solid bodies are usually considered to be classed under the following heads, and the formulæ for calculating their resistances have been deduced from the known laws of mechanics. 1. When one extremity of the beam is firmly embedded in masonry at one end and acted upon by a force, P, applied at the other; then, calling the lever of the beam L; the resistance to compression and extension, R; the moment of inertia of the beam at the point of its bedding, I; and the distance of the line of the neutral fibres from the most distant point of the section of the part fixed, n;

$$\mathrm{PL} = \frac{\mathrm{RI}}{n};$$

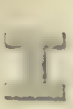
As in a regular prism of a rectangular section $n = \frac{h}{2}$ and the moment of inertia is $\mathrm{I} = \frac{bh^3}{6}$; this formula becomes $\mathrm{PL} = \frac{\mathrm{R}bh^2}{12}$, in which b = the transverse section of the prism perpendicular to the direction of the force P, and h = the section parallel to that direction. The deflection f would be represented by $f = \frac{4\mathrm{PL}^3}{\mathrm{E}bh^3}$; in which the new term E represents the modulus of elasticity.



2. If the solid be of the form shown, then calling b' the internal dimension in the same direction as b; and h' the internal dimension in the same direction as h; then,

$$\mathrm{PL} = \frac{\mathrm{R}(bh^3 - b'h'^3)}{6h};\ \text{and}$$

$$f = \frac{4\mathrm{PL}^3}{\mathrm{E}(bh^3 - b'h'^3)}$$ retaining the preceding notation.



3. In a beam of the section in the margin, calling b' the sum of the two deficiencies from the full section, and h their height, then also, $\mathrm{PL} = \frac{\mathrm{R}(bh^3 - b'h'^3)}{6h}$; and $f = \frac{4\mathrm{PL}}{\mathrm{E}(bh^3 - b'h'^3)}$.

4. The section being circular, and the radius $= r$; then the formulæ become $\mathrm{PL} = \frac{\mathrm{R}\pi r^3}{4}$, and $f = \frac{4\mathrm{PL}^3}{3\pi\mathrm{E}r^4}$; when the section is circular and hollow, calling r the external, and r' the internal radius, the formulæ become $\mathrm{PL} = \frac{\mathrm{R}\pi(r^4 - r'^4)}{4r}$; and $f = \frac{4\mathrm{PL}^3}{3\pi\mathrm{E}(r^4 - r'^4)}$.

5. If now the beam under consideration be carried at a point in its length, and be acted upon at its extremities by two forces which balance one another upon this point of support, the formula for a prismatic beam of a rectangular section becomes,—(calling m the leverage of the force acting at one end, and n the leverage of the force acting on the other; so that $m + n = \mathrm{L}$ the total length of the prism, and $p + q = \mathrm{P}$ the total load;) $\frac{pm + qn}{2} = \frac{\mathrm{R}bh^2}{6}$: and if $m = n = \frac{\mathrm{L}}{2}$, or if the point of support be in the middle of the length, then $\frac{\mathrm{PL}}{4} = \frac{\mathrm{R}bh^2}{6}$.

6. If the load applied to a prism, fixed at one of its extremities, instead of being applied at the other extremity, be evenly distributed over its length, then the load per unity of length being called p, the total load becomes $p\mathrm{L}$; and $\frac{\mathrm{L}}{2}$, the leverage of the total load $p\mathrm{L}$; the formulæ expressing the fundamental conditions of resistance become $\frac{p\mathrm{L}^2}{2} = \frac{\mathrm{RI}}{n}$; and $\frac{p\mathrm{L}^4}{8} = \mathrm{EI}f$, retaining the preceding notation for the old terms. From these formulæ, it appears that a beam loaded uniformly over its whole length, can resist an effort which would be double the one required to break it if applied only at the extremity the farthest removed from the section of rupture; and in order to produce equal deflections at the extremity, the load, distributed evenly over the whole length, should bear to the load applied solely at the extremity, the proportion of 8 : 3.

7. In the case of a beam resting upon two points of support at its extremities, if we suppose that the weight of the beam itself can be neglected, and that the weight, or load, P, be placed on the middle of its length; then as the effect upon the beam would be the same as if it had been fixed in the middle, and loaded at each end, by a weight $= \frac{\mathrm{P}}{2}$, the first set of formulæ would apply, excepting that P would be replaced by $\frac{\mathrm{P}}{2}$ and L by $\frac{\mathrm{L}}{2}$; so that for a rectangular prism the formulæ become $\frac{\mathrm{PL}}{4} = \frac{\mathrm{RI}}{n}$; and $f = \frac{\mathrm{PL}^3}{4\mathrm{E}bh^3}$. From this it appears that a beam supported at the extremities, and loaded in the middle, is able to support a load four times as great as a similar beam fixed at one end and loaded in the middle; and that the deflection would be sixteen times less than in the latter case. If the load, instead of being concentrated in the centre, were evenly distributed over the length, and the load per unity of length be called p, the total load would be $p\mathrm{L}$, and the formulæ would become $\frac{p\mathrm{L}^2}{8} = \frac{\mathrm{RI}}{n}$; and $f = \frac{5p\mathrm{L}^4}{384\,\mathrm{EI}}$.

It has been proved, both theoretically and practically, that a beam fastened at both ends will bear a load applied in the middle of its clear span, which would be double the one it would be able to support if it merely rested upon two points of support, and that the deflection in the former case would be four times less than it would be in the latter. As it generally happens that in building operations, beams and joists have bearings of only about one foot (which is insufficient to constitute an effective fixing of their extremities), it is essential to calculate their dimensions on the supposition that they are merely beams resting on two points of support.

Before closing these remarks on compression and extension, it may be desirable to add a few practical observations on the resistance of materials used in buildings. These are, 1st, that as the form of greatest resistance is almost always one in which the mass of the elements is concentrated at the top and bottom of a beam, leaving the portion about the neutral axis as light as possible, it follows that with plastic materials it is advisable to make the sections of the beam of a girder shape, that is to say with top and bottom flanges: the material must be distributed in those flanges according to its powers of resistance to efforts either of compression or of extension. [GIRDER.] 2nd, It is usually considered that a load acting with a shock, or able to produce sudden vibrations, acts in a manner far more injurious than if the same load were to act steadily; and in practice engineers have adopted the rule of never exposing a construction to a rolling weight greater than ⅙ of the permanent breaking weight. 3rd, It is usually considered that a deflection of $\frac{1}{400}$ of the span, is the maximum which should be tolerated; but that the safe deflection would only be $\frac{1}{2000}$ of the span. 4th, The resistance of cast iron to compression is, compared to its resistance to extension, as 6½ (nearly) to 1; on the contrary the resistance of wrought iron to compression is, compared to its resistance to extension, as 4 to 5.

Torsion.—With respect to the resistance to torsion it may be observed, that in a prismatic body submitted to such an action, the relation of the effort to the angle of torsion is constant for the same material, so long as the limits of elasticity are not exceeded. Calling this relation G; the effort Q; and the angle of torsion θ, for a rod of a given unity of length and of section; we have $\frac{\mathrm{Q}}{\theta} = \mathrm{G}$, which may be called the co-efficient of torsion. If then, we call P the force tending to twist a cylindrical or prismatic solid, in a plane normal to the axis; R, the radius of the leverage with which P acts; t, the angle of torsion; L, the length of the solid; and I, the moment of polar inertia; we have the moment of the force $\mathrm{P} = \mathrm{PR} = \frac{\mathrm{G}t}{\mathrm{L}}\mathrm{I}$; and from this we derive $t = \frac{\mathrm{PR} \times \mathrm{L}}{\mathrm{GI}}$. It is considered that the value of I becomes,

when the section is circular, $\mathrm{I} = \frac{\pi r^2}{2}$;

when the section is rectangular, $\mathrm{I} = \frac{b^3h^3}{3(b^2 + h^2)}$;

when the section is square, $I = \frac{q^4}{6}$,

calling *r* the radius of the solid cylinder; *b* and *h* the sides of the rectangle, and *q* the side of the square; when the section is annular, calling the external and internal radii respectively *r* and *r′*, the value becomes $I = \frac{\pi(r^4 - r'^4)}{2}$. In practice, the angle of torsion is usually made, $t = 0{\cdot}0005\frac{L}{n}$, in which *n* = the distance from the axis to the most distant fibre from itself. Mr. Bevan ('Philos. Trans.,' 1829) has given a table of the modulus of torsion for the different kinds of wood, which is appended; and he also states that for metals the modulus of torsion is equal to $\frac{1}{16}$ of the modulus of elasticity.

Detrusion.—The resistance to detrusion is at times called into action, in timber or iron construction; and therefore requires to be noticed. It has not been made the subject of any direct experiments, but it is supposed in fir timber to be equal to 592 lbs. per square inch in the direction of the force; in cast iron, 73,000 lbs.; and in wrought iron, from 45,000 to 53,000 lbs.

In Warr's 'Construction of Machinery,' a very useful comparative table of the various kinds of resistances of the principal classes of materials used in the arts is given as follows:—

Material.	Compression.	Tension.	Transverse.
Timber	1000	1900	85·1
Cast iron	1000	158	19·8
Stone	1000	100	10·0
Glass	1000	123	10·0

TABLE OF VARIOUS PROPERTIES OF MATERIALS.

Material.	Specific gravity.	Weight per cubic foot in lbs.	Tenacity in lbs.	Crushing force in lbs. per square inch.	Modulus of Elasticity.
Alder	0·800	50·00	14,186	6,895	
Antimony, cast	4·500	281·25	1,066		
Ash, densest	0·845	53·81	17,207	9,363	1,664,800
Beech	·822 to ·690	53·37 to 43·12	17,850	9,363	1,353,600
Birch	0·792	49·50	15,000	6,402	1,562,400
Bismuth, cast	9·810	613·87	3,250		
Box, dry	0·960	60·00	19,891	10,299	
Brass, cast	8·390	525·00	17,968	10,304	8,930,000
„ wire drawn	8·544	534·00			
Brick, red	2·168	135·50	280	807	
„ pale	2·085	130·31	300	562	
Brickwork	1·800	112·50		270	
Cedar, seasoned	0·753	47·06		4,912	
Chalk	2·784	174·00		334	
Clay	1·919	119·93			
Copper, cast	8·607	537·93	19,072	117,088	
„ wire drawn	8·878	560·00	61,228	103,040	
Deal, Christiania	0·698	43·62	12,400		1,672,000
„ Memel	0·590	36·87			1,535,200
Elm, seasoned	0·588	36·37	13,489	10,331	699,840
Fir, Riga	0·753	47·06	12,857	6,586	869,600
Glass, plate	2·453	153·31	9,420		
Granite, Cornish	2·662	166·30	14,302		
Hawthorn	0·910	58·12	10,500		
Hornbeam	0·760	53·75	20,240	7,289	
Iron, bar	7·700	481·20	57,120	56,000	
„ wire			89,000		
„ sheets			31,360		
„ cast, cold blast	7·066	441·62	16,683	106,375	17,270,500
„ hot blast	7·046	440·37	13,503	108,540	16,085,000
Larch	0·522	32·62	10,220	3,201	897,600
Lead, cast	11·446	717·45	1,824	7,728	720,000
„ sheet	11·407	712·93	3,328		
Limestone, box	1·893	114·93			
„ Portland	2·145	134·06		10,284	
Lime tree	0·760	47·50	23,500		
Marble, white	2·638	164·87		13,620	2,520,000
„ black	2·695	168·25		20,742	
Mortar	1·751	107·18	50		
Oak, English	0·934	58·37	17,300	9,509	1,451,200
„ Dantzic	0·756	47·24	12,780		
„ African	0·972	60·75			
Pitch pine	0·660	41·25	7,818	5,445	1,225,600
Slate	2·888	180·50	12,800		1,580,000
Sandstone, Craigleith	2·266	141·62		5,800	
„ Yorkshire	2·320	145·00			
Steel, soft	7·780	486·25	120,000		
„ razor-tempered	7·840	490·00	150,000		2,900,000
Teak, dry	0·657	41·06	15,000	12,101	2,414,400
Tin, cast	7·291	455·68	5,322	15,456	4,608,000
Tile, common	1·815	113·43			
Willow, dry	0·390	24·37	14,000		
Zinc	7·028	439·25			13,680,000

Table, from Warr's 'Construction of Machinery,' of specific gravities and of the values of s, the co-efficient of the specific strength of materials, for the application of the formula usually employed to calculate the breaking weight of beams, $\frac{\text{breadth} \times \text{depth}^2 \times s}{\text{length in feet.}}$ = breaking weight in lbs.; both the breadth and depth being in inches.

Material.	Specific gravity.	Value of S.
Ash	0·760	506
Beech	0·690	390
Birch	0·711	482
Elm	0·579	200
English oak	0·829	424
Pitch pine	0·740	432
Dantzic fir	0·649	356
Deal, Christiania	0·689	303
Mahogany	0·688	430
Teak	0·729	527
Cast iron	7·066	1980
Hard limestone, about	1·800	78
Soft ditto „	2·200	69
Brick, common „	2·090	64

TABLE, BY MR. BEVAN, OF MODULI OF TORSION OF WOODS.

Kind of Wood.	Specific gravity.	Modulus in lbs.	Remarks.
Acacia	·795	28,293	Not quite dry.
Alder	·55	16,221	Cross grained.
Apple	·726	20,397	
Ash		20,300	Of my own planting.
„ mountain	·449	13,933	
Beech		21,243	
Birch		17,250	
Box	·99	30,000	Old and very dry.
Brazil wood	1·05	37,800	Old and very dry.
Cane		21,500	Influenced by the hard [surfaces.
Cedar, scented		12,500	
Cherry	·71	22,800	
Chestnut, sweet		18,360	
„ horse	·615	22,205	
Crab	·763	22,738	
Damson		23,500	
Deal, Christiania	·38	11,220	
Elder	·755	22,285	
Elm		13,500	
Fir, Scotch		13,700	
Hazel	·83	26,325	Not quite dry.
Holly		20,543	
Hornbean	·86	26,411	Not quite dry.
Laburnum		18,000	Green, or fresh cut.
Lancewood	1·01	25,245	
Larch	·58	18,967	
Lime, or Linden	·675	18,309	
Maple	·735	23,947	Partly cross-grained.
Oak, English		20,000	
„ Hamburg	·693	12,000	
„ Dantzic	·586	16,500	
„ (from bog)	·67	14,500	
Ozier		18,700	
Pear	·72	18,115	
Pine, St. Petersburg		10,500	Fresh.
„ St. Petersburg		13,030	Four or five years old.
„ Memel		15,000	
„ American		14,750	
Plane	·59	17,617	
Plum	·79	23,700	
Poplar	·333	9,473	
Satin wood	1·02	30,000	
Sallow		18,600	
Sycamore		22,900	
Teak		16,800	Old, partially decayed.
„ Africa		27,300	
Walnut	·572	19,784	

RESOLUTION. [SOLUTION.] The resolution and solution of a question are, in common language, the same things. The word is also used as opposed to COMPOSITION.

RESOLUTION IN MUSIC. [DISCORD; HARMONY.]

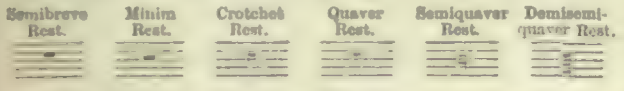
RESPIRATOR, or breath-warmer, an instrument invented and brought into use by Mr. Julius Jeffreys, for giving warmth to the air drawn into the lungs in breathing, and thereby enabling invalids to enjoy the benefits of exercise in the open air without injury or inconvenience.

The common practice of wrapping up the lower part of the face in a woollen covering warms the air inhaled through it very imperfectly, and in an unwholesome manner, by mixing with it a portion of the impure air exhaled from the lungs, and detained in its bulky folds. A woollen wrapper, being a non-conductor of heat, can act in no other way. In the respirator this disadvantage is avoided by causing the air discharged from the lungs to pass through several layers of very fine wire, fixed so near together that the breath passing through them is almost infinitely divided, its warmth being abstracted by the metal, which, being an excellent conductor of heat, freely imparts it to the fresh cold air drawn, or, as it were, filtered through it. The compactness of the instrument is such that there is no room for the lodgment of the impure air expelled from the lungs, and consequent contamination of that inhaled; and the condensation of moisture on the wires corrects the injurious dryness of the atmosphere in some northerly winds.

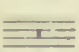
The means by which these objects are attained in the respirator display much ingenuity in contrivance, and no ordinary degree of skill in the execution. The inventor considers it necessary that about twenty layers of metal-work should be used, and, in order to make the instrument as light and compact as possible, each layer is required to be exceedingly thin. The apparatus usually consists of from eight to twelve frames of sheet-silver or other metal, about three inches and a half long, one inch and a half wide, and $\frac{1}{200}$th part of an inch thick; the metal of which is pierced away by machinery so as to leave merely a narrow frame containing six vertical bars of $\frac{1}{10}$th and five horizontal bars $\frac{1}{40}$th of an inch wide. On both sides of each of these frames a layer of wires an inch and a half long and $\frac{1}{100}$th of an inch thick is soldered, care being taken to connect each wire, not only with the top and bottom bars of the frame, but also with each of the five horizontal bars. The wires are laid about $\frac{1}{200}$th part of an inch apart, and are so numerous that a large respirator of high power contains 2000 feet of wire, divided into about 12,000 pieces, and soldered to the frames at more than 80,000 distinct points. The frames or lattices of wire-work are fixed parallel to each other, and kept a short distance apart by small studs of a substance which is a slow conductor of heat, so that the inner layer is always kept, as nearly as possible, at the temperature of the air expelled from the lungs, and each successive layer diminishes in warmth, till the outer one is nearly as cold as the external air. The curious and philosophical application of a non-conducting medium between the metallic screens is essential to the perfect action of the instrument, as without it the heat would be equally diffused, and no part of the metal-work could retain more than half the temperature of the breath. By this arrangement the air inhaled, finding each layer of wire warmer than the preceding, is gradually raised, in respirators of the highest power, to the greatest attainable temperature. The most powerful respirators have twenty four layers of wire-work, those of medium power sixteen, and the lowest power eight. The whole of the wire-work is bent into a curved form, and enclosed in a bordering or case of soft leather, which is made to fit closely to the face of the wearer, so as to prevent the entrance of air otherwise than through the metal-work, and to hold the latter in such a position that the lips do not come in contact with the wires. An outer covering of silk or other material is added, having an aperture in which is inserted a very thin plate of silver, perforated with minute holes, and to which a dark colour is imparted by a chemical operation, to serve as a screen to the wire-work, which it hides without impeding the passage of air as most textile fabrics would do. Recently however a very fine and open woollen fabric has been made use of in lieu of the perforated plate, to suit the wishes of some persons to whom the appearance of the instrument was an objection. The common or *oral* respirator covers the mouth only; but a variety called the *orinasal* respirator encloses the nostrils also. A piece of sponge attached to the lower edge of the instrument collects the moisture condensed from the breath, and it, as well as the metal-work and leather mounting, may be detached from the outer covering and cleaned when necessary.

RESPONDENTIA. [BOTTOMRY.]

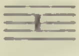
REST, in music, a character denoting silence; a cessation of sound equal in duration to the note represented by the *rest*. As there are six musical characters called notes, so there are as many rests. Ex.:—



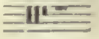
The breve rest, to be found in old music, is a short thick bar connecting two lines. Ex.:—



In separate vocal and instrumental parts, a character uniting three lines, and indicating a rest four bars in duration, is employed. Ex.:—



The following is the manner of directing a silence, or rest, of eleven bars, in any of the modern times or measures:—



RESTITUTION (in Law) *of lands*. Where a forcible entry or detainer of lands is on inquiry duly found, or after conviction under an indictment for a forcible entry, the court before whom the inquiry is made, shall cause *restitution* of the lands to be made to the party who has been turned out of possession. (Com., 'Dig.,' 'Forceable Entry,' D 5, &c.)

Restitution of goods. By 7 & 8 Geo. IV., c. 29, s. 57 (re-enacting a statute of Henry VIII.), if any person guilty of a felony or misdemeanor in stealing, converting, or receiving any property, shall be indicted for such offence by the owner or his executor, and convicted, the property shall be restored, and the court shall have power to award writs of restitution for the property, or order it to be restored in a summary manner. If it appears, however, that a valuable security has been *bonâ fide* paid or discharged by some person liable to pay it, or being a negotiable instrument has been *bonâ fide* taken or received by transfer or delivery by some person for a valuable consideration, without any reasonable ground to suspect that it had been stolen, &c., then the court shall not order the restitution of such security.

Restitution also formerly took place where the heir of one attainted of treason was relieved from the consequences of the attainder. (3 'Inst.' 'Restitution.')

RESTORATIONS, in Architecture, a term applied to drawings intended to show ancient buildings according to their original design, as made out from their existing remains, aided by such descriptions or hints as are to be obtained from classic authors, or from the representations of them on coins. The term restoration is, however, now more commonly applied to the actual *reconstruction* of an old building, where that reconstruction has for its object to reproduce the leading architectural features and ornamental details, so as to resemble as nearly as practicable those of the original building. In this sense of the term, a very large proportion of the Gothic churches in this country have been *restored* during the last few years; while many others are undergoing that process.

RESULTING USES. [USES.]

RESULTING TRUSTS. [TRUST AND TRUSTEE.]

RESUSCITATION (from *resuscito*, to arouse, to revive), the restoring to animation of persons apparently dead. Under this term, strictly speaking, should be considered the restoration of all cases of suspended animation, whether arising from disease or as a result of asphyxia; yet it is chiefly made use of to designate the recovery of persons from this latter condition. The symptoms, physiological conditions, and causes of asphyxia are fully described under that head; the treatment of it generally, and of its different varieties, was reserved for the present article. Although the suspension of all the vital actions of the system which takes place in asphyxia has originated from the temporary interruption of a single function, yet the derangement which has followed is of so complicated a nature, and extends to so great a number of important organs, that the mere re-establishment of the function primarily disturbed is not immediately followed by the restoration of the rest, and by the removal of all the mischief. The mere introduction of fresh air into the lungs cannot at once restore the action of the heart, or of the diaphragm, and of the other muscles which are concerned in respiration, because these muscles have lost either the whole or the greater part of their irritability, in consequence of having been supplied with venous instead of arterial blood. While the first and principal object is to bring the blood contained in the pulmonary vessels under the influence of atmospheric air, attention must at the same time be paid to the state of the circulation, and to the restoration of those powers by which that function, as well as respiration, is to be carried on. The first of these objects can be accomplished by the artificial inflation of the lungs; the second is to be attempted by the judicious application of stimulants to various parts of the body. The details of these processes have been already given in the article DROWNING. But asphyxia may also occur from the presence of foreign bodies in the larynx, which mechanically prevent the inflation of the lungs through the natural passage; in this case the operation of tracheotomy must be resorted to, and the pipe of the bellows must be introduced into the windpipe through the opening thus artificially made. In addition to the employment of artificial respiration, and the use of external and internal stimulants, many physicians have recommended blood-letting; but besides the doubtful advantage which sometimes may accrue from this practice, it is not always possible, and such is especially the case if the asphyxia is of long continuance. In general, the effects of blood-letting would be injurious, and it is now rarely had recourse to unless there are very unequivocal indications of great pressure on the brain. Whatever may be the means that we employ, they should be persevered in till the signs of death are no longer equivocal. Dr. Currie, in his 'Observations on Apparent Death,' recommends their being persisted in for at least six hours; the French writers mention the commencement of rigidity of the limbs as the only criterion of the hopelessness of continuing our efforts. The first signs of returning animation are slight convulsive twitchings in the muscles of respiration, which give rise to gaspings and sighings. By degrees these spontaneous efforts become more regular, and natural respiration is restored; and together with it the circulation returns. The first return to sensation is usually attended with great suffering, and the utmost attention is required to guard against the dangerous symptoms which sometimes show themselves at this period.

RETABLE, called most commonly by English architectural writers *Reredos*, the screen of wood or stone placed at the back of and above the altar in mediæval churches. Retables do not appear to have come were not usual till towards the end of the 13th century, the throne of the bishop having been till then usually placed at the end of the apse and behind the altar, so that anything rising above the altar would have obstructed the view of the congregation. At first the retable was merely a low screen, with a single row of sculptured figures placed in niches. But in the 15th century retables, whether of marble, stone, or wood, were made of large size, and adorned with a profusion of sculpture embodying the best sculptural art of the period. In Germany especially, they were often of extravagant height and costliness, reaching sometimes to the chancel roof, and covered with a multitude of small figures. In our own country they sometimes extended quite across the chancel. The leading events of the lives of the saint to whom the altar was dedicated were now often represented, the carved figures being coloured, and the ground gilt: characteristic examples may be seen at the South Kensington Museum, in one of French work with a large number of figures in high relief, of about 1500; and one of carved oak of the latter part of the 15th century of Flemish work, said to have been brought from the cathedral of St. Bavon, Ghent; while in the same collection is a still more remarkable triptych retable of the 15th century (No. 131) of German work, in which the life and martyrdom of St. Margaret are represented by numerous small figures arranged in compartments, which retain much of the original colour and gilding. Several other retables of mediæval date are in the same museum, and also one or two in marble of Italian renaissance work. Portable diptych and triptych retables were much used in the 16th century, of which some very beautiful specimens in ivory and in enamel are at South Kensington. Many of the churches of the continent retain fine examples of mediæval retables; and many fine reredoses, as the fixed retable was here called, may be seen, more or less mutilated, in our own Gothic churches, as at Durham, Gloucester, and Bristol cathedrals, St. Alban's Abbey Church, Henry VII.'s Chapel, Westminster Abbey, St. Saviour's, Southwark, &c.

RETAINER. [Executor; Serjeant-at-Law.]

RETAINING WALL is the term used for a wall erected to resist the thrust of a mass of earth, or of a volume of water stored in a reservoir. In consequence of the variable nature of the materials to be retained, as well as of the materials of which the walls themselves are composed, the practical application of the mechanical laws usually adopted for calculating the thicknesses of this class of works is more empirical than is usually the case in the ordinary operations of building. The following are, however, some of the generally received principles adopted by engineers in the construction of these walls.

Navier, who has applied the higher analysis to the investigation of the laws of the stability of buildings, gives a formula for the thickness of retaining walls, and a table of the weights of the materials commonly dealt with. The table is as follows, in English weights and dimensions:—

Material.		lbs.
Vegetable earth,	per yard, cube	2352
Clayey earth	,, ...	2688
Clay	,, ...	3192
Stiff earth, with pebbles	,, ...	3847
Marl	,, ...	2688
Mud	,, ...	2772
Fine dry sand	,, ...	2352
Wet do.	,, ...	3192
Argillaceous sand	,, ...	2940
Wet river sand	,, ...	3024
Rubble masonry	,, ...	3360
Ashlar	,, ...	4536
Brickwork	,, ...	3024

The formula for walls with two vertical faces is; calling

x, the thickness sought, in yards and decimals,
h, the height of the wall above its base, in yards,
P, the weight per yard cube of the wall,
P', the weight of the earth or other material,
θ, the angle that material, if left free, would form with the vertical line passing through the foot of the slope;

$$\text{then } x = 0{\cdot}59\, h \text{ tangent } \frac{\theta}{2}\sqrt{\frac{P'}{P}}$$

This formula would give thicknesses considerably less than those usually adopted in practice; for the general rule adopted by engineers is to make the thickness of retaining walls equal, on the average, to 1-3rd of the height, or 0·33 h. It must, however, be borne in mind, that there is no allowance made in the formula for the numerous disturbing causes which are frequently met with, such as the subsidence of the ground; nor does it take into account the cohesion of the earth, nor that of the masonry; it is, in fact, only founded upon the theoretical conditions of the equilibrium of the materials. It is even desirable in addition to the extra thickness thus given in practice to the walls, beyond that which is required by the strict application of theoretical laws, to give a batter to the external faces equal to 1-24th of the height. A greater batter than this would be objectionable, on account of its catching and retaining the falling rain; and it is desirable that the internal face of the wall should be formed in such a manner as not to hold up any water which might filter through the earth piled against it. In most cases, also, the resistance of retaining walls is increased by the introduction of counterforts; especially when the length of the embankment, or earthwork, to be retained is considerable.

Retaining walls used in situations where the earth at their backs is liable to become saturated with water by tidal action, or by the capillary attraction of the earth, must be established on the supposition that their backing becomes in fact a semi-fluid, denser than water, and which consequently has no angle of repose. Careful observations on the state of the walls in the French ports on the Channel, have shown that in many cases those walls have yielded when their mean thickness has even been as much as 0·41 : 1·00; and it therefore would appear that in such cases it is not safe to keep the ratio of the mean thickness below 0·45 or 0·50 to 1·00. In reservoir walls of masonry, the thickness should be made, practically, double that of ordinary earth-retaining walls, as indicated by theory; and especial care should be taken to ensure the adhesion of the wall to its foundations; for it is found that the expression of the resistance of these walls to overthrow is 0·41 h, while that of the resistance to longitudinal displacement is 0·50 h. The summit of the retaining wall of a reservoir should be made at least equal to 1-3rd or 1-4th of the head of water; and the effect of the surcharge of the masonry above the water-line may be neglected in estimating the statical resistance.

The reader who would desire to study the strict theory of this question would do well to examine the 'Mémoires' by Coulomb, Mayniel, and Prony, 'Sur la Poussée des Terres;' Navier's 'Leçons de la Mécanique;' Pasley's 'Course of Military Instruction;' Moseley's 'Engineering and Architecture;' but the most condensed and practical notice upon the subject is to be found in Carr's invaluable 'Synopsis of Practical Philosophy,' under the head 'Earth.' The following table of the angle formed by the natural slope of the materials enumerated may be found useful in applying Navier's formula, previously given, when it may be desired to calculate the resistance of a wall rather more closely than it is found necessary to do in practice:—

1. Fine dry sand forms with the vertical line a slope, having an angle of 69°; sometimes the angle is, however, = 55½, when the sand has been well rammed.			
2. Vegetable earth	do.	of	55½°
3. Loose shingle	do.	of	51°
4. Ordinary earth, well dried and pulverised forms an angle of			43° 10′
5. Rubble, small and rough	do.	of	37½°
6. Do. do. slightly moistened	do.	of	36°
7. Densest and most compact sand	do.	of	35°

From this table it appears that θ usually ranges between 35° and 70°; for water and for extremely fluid mud θ becomes = 9°.

RETARDATION. [Acceleration.]

RETI'CULUS, or RETICULUM RHOMBOIDA'LE (the rhomboidal network formerly used to divide the field of a telescope), a southern constellation of Lacaille, situated directly between the great stars of Argo and Eridanus.

Character.	No. in Catalogue of Lacaille.	No. in Catalogue of British Association.	Magnitude.
β	292	1197	4
α	329	1336	3

RETINAPHTHA. [Turpentine.]

RETINOLE. [Turpentine.]

RETINYL. [Turpentine.]

RETISTERENE. A name given by Dumas to metanaphthaline.

RETORT, a chemical vessel in which distillation or decomposition is effected by the application of heat; for different purposes retorts are made of glass, earthenware, and metal.

Glass retorts are usually of the annexed form, with a receiver attached; they may be employed for the preparation of such products as do not require any extraordinary degree of cold for the condensation of their vapour: such a liquid is nitric acid. In this cut a represents the body of the retort, b the neck, and c is the receiver.

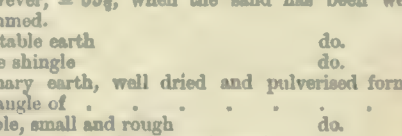


Fig. 1.

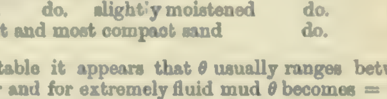


Fig. 2.

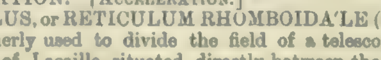


Fig. 3.

To prepare this acid, nitrate of potash is carefully conveyed by the neck into the body of the retort, and then sulphuric acid is added to it by means of the retort funnel *d*, which prevents any of this acid from remaining in the neck of the retort, and being washed down by and contaminating the nitric acid, as it condenses and passes into the receiver. In this case, when heat is applied to the retort, nitric acid and water rise together in vapour from the body of the retort, and are condensed in the neck; but when the product is more difficult of condensation, the neck of the retort is lengthened by placing an adapter *e* between it and the receiver, to both of which it is secured by a lute; it being understood that the wider end slips over the aperture of the retort, and the narrower one is admitted into the mouth of the receiver. In many cases condensation is accelerated by the use of a Liebig's condenser interposed between the retort and receiver. [CONDENSER.]

A stoppered retort *f* (*fig.* 4) is sometimes used instead of a plain one: these retorts are more expensive, but much more convenient than common ones; for both the dry and the liquid substances to be employed in the operation are passed into the body of the retort through the aperture, which is afterwards secured by a stopper, without having recourse to the retort funnel. Frequently also a quilted or tubulated receiver is used instead of the plain one above described: this is represented by *g*; the tube is inserted into a bottle *h*, and this, when ammonia or other very volatile or difficultly condensible products are distilled, dips into water, or the receiving bottle itself is immersed in water kept cold by ice or by a freezing mixture, as when hydrocyanic acid is distilled: *i* is the stand which supports the retort, and *k* is the lamp by which heat is applied to it.

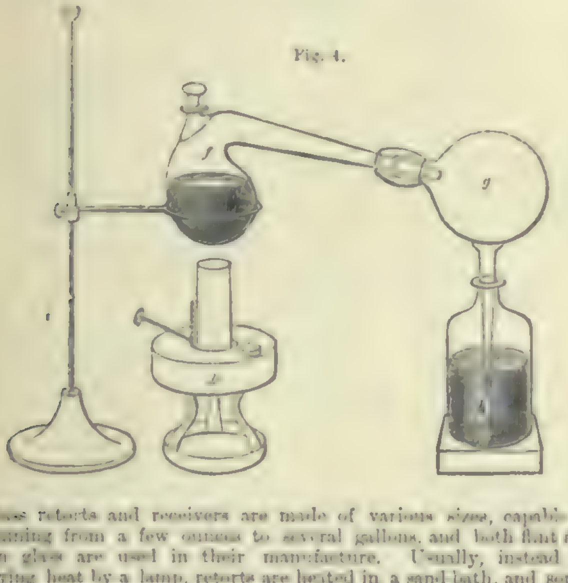


Fig. 4.

Glass retorts and receivers are made of various sizes, capable of containing from a few ounces to several gallons, and both flint and green glass are used in their manufacture. Usually, instead of applying heat by a lamp, retorts are heated in a sand-bath, and sometimes they are subjected to the direct action of the fire; but before this they are very commonly protected by a coating of lute. [LUTE.]

In general, when the application of the higher temperatures is required for distillation or decomposition, earthen retorts are employed. In preparing hydrofluoric acid, lead is used; and in concentrating sulphuric acid, platinum retorts are now largely employed, and would be universally so, were it not for their very high price.

In the destructive distillation of coal [GAS LIGHTING] iron retorts are used, and also, on the small scale, for obtaining oxygen from the peroxide of manganese, and various other chemical operations.

RETRENCHMENT, in Fortification, is a work constructed within another, in order to prolong the defence of the latter by impeding or preventing the formation of lodgments when the enemy has gained possession of it; or to afford protection to the defenders till they can retreat with safety or obtain a capitulation. In the latter instances the interior work is called by the French engineers a *reduit*.

Every principal work in permanent fortification is provided with its retrenchment or redout; and some of these, as the redout of the ravelin, and of the re-entering places of arms, are constructed at the same time as the work itself, while others, as the retrenchments within a bastion, are generally executed but a short time before they are wanted.

In 1552, when Metz was besieged by Charles V., the Duke of Guise, who commanded in the town, by constructing new ramparts within the old, as fast as the latter were destroyed by the besiegers, succeeded at length in compelling the emperor to raise the siege; and at the siege of Candia (1666–1669), the Venetians raised a rampart from one curtain to the next in rear of the gorge of the bastion St. Andrea, so that, long after that bastion was breached and taken, the town continued to hold out. Such prolonged defences are now rare, and the governor of a fortress is considered as having fulfilled his duty if he do not surrender till a breach has been made in the rampart of the enceinte; though if the bastion were retrenched, he might sustain an assault without any risk of being refused a capitulation, or of seeing the town given up to be plundered. In the event of the assailants gaining the top of the breach, the defendants would be able to retreat within the entrenchment, the fire from which might then be concentrated upon the enemy while confined within the comparatively narrow space between the faces of the bastion.

The kind of retrenchment proposed by Cormontaingne for the bastion of a fortress is a rampart or parapet extending across the interior of the work in a right line, or rather in the form of a tenaille. [X, FORTIFICATION.] Its extremities join the faces of the bastion at 20 or 30 yards in front of the shoulders, by which means the flank is left quite free, so that all its artillery can be employed in defence of the main ditch, and there is room between the retrenchment and the shoulder of the bastion for two guns, by which the interior of the ravelin and the ditch of its reduit might be defended, if necessary, even after the enemy had made a lodgment in the bastion.

As the retrenchment in this situation is liable to be enfiladed by a battery of the besiegers on the glacis before the collateral bastion, it is proposed that another should be formed in rear of the gorge of the bastion attacked; and as in this case there would be sufficient room, the retrenchment may be in the form of a front of fortification with a revetted scarp and counterscarp.

The ditch in front of a retrenchment, as at X in FORTIFICATION, is cut quite through the parapet of the bastion, in order to prevent the enemy, after the assault at the breach, from passing along the top of that parapet, and getting to the rear of the retrenchment. This opening of the parapet does not, however, go lower than the level of the cordon of the scarp revetment, in order to avoid diminishing the height of that scarp, and thus offering a facility to the enemy, should he attempt to escalade the work at that place.

Cormontaingne proposed to retrench small bastions by constructing within them cavaliers of the same form as the bastion itself, and having a command of 5 or 6 feet above it. The fire from this high parapet might give the work some advantages during the progress of the siege; but from its figure a cavalier appears to be less proper than a retrenchment in the form of a tenaille, for the defence of the terreplein at the top of the breach.

It is evident that full bastions like A [FORTIFICATION] must be more convenient for being retrenched than those which are of the kind called hollow, as B; since less earth is wanted to raise the retrenchment to the required level, and the scarps are covered by the opposite side of the ditch from the view of the enemy at the top of the breach. The most simple manner of retrenching a hollow bastion would be that of retaining the rampart on the interior side, where it is usually 10 or 12 feet high, by a wall, and cutting a deep ditch at the foot; then forming a traverse across the terreplein of the rampart on each face (at 20 or 30 yards from the salient angle of the bastion) with a ditch in front. The enemy, in gaining the top of the breach, would then find himself arrested by these obstacles, and exposed to the fire of the defenders, till ladders and the support of a large body of troops could be obtained. The bastions of Ciudad Rodrigo, Badajos, and St. Sebastian were retrenched in this manner when those fortresses were besieged by the British and their allies during the Peninsular war.

Vauban, having observed that the ravelin was sometimes abandoned by the defenders previously to an expected assault, on account of the difficulty of retreating across the main ditch under a fire from batteries on the glacis before the bastions, constructed, in the interior of that work, another, which might afford the defenders protection till the coming night would permit them to retire in safety. This work was at first only a wall, pierced with loop-holes for musketry and covering the steps at the gorge; but when Vauban increased the size of the ravelin, he made this redout, or retrenchment, to consist of a rampart and parapet similar to those of the ravelin itself, as at Neuf Brisac; and Cormontaingne subsequently enlarged the work, so as to render it a second ravelin, as at Y [FORTIFICATION]. This spacious retrenchment contributes much to the prolongation of the defence of the ravelin, since it is capable of containing a large body of troops; and each of its flanks carry three guns, whose fire might be directed against the counter-battery at the salient of the bastion, or might serve for the defence of the breach in the face of the latter, should the enemy attempt to make an assault before he has obtained possession of the reduit. But to take this last, it would be necessary to breach its faces either by artillery or by mining; and the passage of its ditches would be difficult under a close fire from the ramparts near the shoulders of the neighbouring bastions.

In order that the defenders might be able to retain possession of the extremities of the ravelin, near the main ditch, after the salient part may have been taken, retrenchments or coupures, as they are called, similar to the traverses, *t*, *t*, &c., are recommended to be formed across the terreplein of the ravelin. Behind these some of the defenders may retire, and keep up a fire against the enemy's lodgment near Z.

When Vauban had enlarged the re-entering places of arms, L [BASTION; FORTIFICATION], he retrenched the interior with stockades, which, by covering the steps leading from the ditches in their rear, protected the retreat of the defenders of the covered way; and Coehorn appears, about the same time, to have constructed brick walls, provided with loopholes, in the places of arms, at Bergen-op-Zoom, for the same purpose. But Cormontaingne, in order to render the defence of the places of arms more obstinate, and to secure more effectually the retreat of the defenders of the covered-way, constructed the redoubts, as w [FORTIFICATION], with parapets of earth 12 or 14 feet thick; and he revetted the sides of their ditches, in order to diminish the risk of a surprise: he also gave them flanks, which he made perpendicular to the covered way, that a fire of light artillery or musketry might be directed from them against the enemy while attempting to crown the salients of the ravelin. These redoubts moreover cover the shoulders of the bastions and the portions of the curtain which might be seen and breached by a fire directed between the flanks of the bastions and the tenailles; and their faces are directed so that they cannot be enfiladed. The crest of their parapet is about four feet higher than that of the glacis in their front.

The advanced works about a fortress are recommended to be retrenched with round towers of masonry, provided with upper and lower tiers of loopholes for musketry. These are called *safety redoubts;* and in Montalembert's 'Fortification Perpendiculaire,' such towers are constructed to carry artillery within the rampart of the enceinte.

For retrenchments in field fortification, see BLOCKHOUSE.

RETROGRADE, moving backwards, as opposed to DIRECT. In astronomy all motion from east to west is retrograde: thus the apparent motion of the heavens is retrograde, and the earth's diurnal motion, which causes it, is direct.

RETURN OF CATTLE, &c., is a term applied to the restoration of cattle, &c., distrained, to the party by whom they were distrained, after it has been ascertained that the distress was rightfully taken. The restoration of the cattle, &c., distrained to the owner is not called a return, but a replevin. [REPLEVIN.]

RETURN OF WRITS. When process [PROCESS] issues, the party to whom it is directed is commonly required to do a specified act, to certify the court in what manner the command has been executed, and at the same time to produce or *return* the process itself. Hence the whole answer to the process is called the return. [SHERIFF.]

REVELATION (removal of a covering, or discovery) signifies, in theology, a preternatural or extraordinary communication made by the Deity to men. The evidence of a revelation may be considered with reference to the party to whom it is first and immediately made; to those who have their knowledge of it immediately from him; and to those who possess only a recorded account of it. It should seem that in the case of the first recipient, the only evidence fully satisfactory must be something external to himself, or unequivocally presenting itself to the judgment of his senses. If it is asked why preternatural intervention is claimed in behalf of those to whom the revelation is delivered by the first receiver of it, and dispensed with in the case of those to whom only the record of it has descended, the answer is, that a miraculous fact is a subject for historical testimony; and if confirmed by that, conveys to future generations the same kind of security which it was intended to afford to those who witnessed it.

In saying that a miracle is the proper test of a revelation, we do not mean to exclude every other kind of proof. We mean only that a miracle is that one species of proof which cannot be spared. Many circumstances may be supposed to have place in a revelation, which would contribute greatly to confirm its reality, and which might with some minds have more influence in inducing acceptance than even the proof of miraculous agency.

We have spoken of a miracle as the test of a revelation, without attempting a definition, believing the common notion of it to be sufficiently accurate for our purpose. For the distinctive character of a miracle, and the possibility of proving it by evidence, the reader may consult the article MIRACLE in this work, and the authors referred to at the end of it. It is presumed that the purpose of the miraculous test is evident. A certain person is converted to the belief of certain truths by an appearance, undoubtedly miraculous, in the sky. The miracle is to him a proof that his conversion is from God. He teaches to others the truths which he has been made to believe: and in doing this performs miracles. These are a proof to them that he is commissioned by God to teach what he delivers; recorded and duly attested, they prove the same to those who have not witnessed them. All the parties, in accepting the test, would reason in the same manner, namely, that the laws of nature could be changed only by God, the author of them, or by his permission; and that he would not change them, or permit them to be changed for the purpose of establishing a falsehood.

To the question, "has a revelation been actually made?" the Christian believes that he has an answer in the possession of the Holy Scriptures, or the books of the Old and New Testament. An account of the contents of these books and an examination of the evidences of the Christian revelation form, of course, no part of the subject of this article: they are noticed under their respective headings. The proofs which we have insisted on as requisite to establish the reality of a revelation generally, must, if rightly assigned, be applicable to this particular one.

We insisted on the primary evidence of miraculous agency in the communication, with corroboration from the matter communicated, the miraculous agency to be so exhibited to the witnesses as to be capable of proof from testimony to others. Particular revelations may be supposed according to the circumstances under which they were given, and the nature of their contents, to admit various topics of evidence; almost all of which however will probably be found to resolve themselves into one or other of these two, though all inquirers may not agree in the classification. We should place for instance under the head of proof from preternatural manifestations, the fulfilment of prophecy in cases supposed to be beyond the reach of human foreknowledge or conjecture; the attested existence of persons exhibiting qualities, moral or intellectual, in kind or degree, not exemplified or to be expected in others of the human race; conduct of men, natural under the supposition that they were conscious and had proof of a divine commission, but otherwise unaccountable according to any known motives of human action.

The purpose and value of what may be called the corroborative evidence as distinguished from that founded on miraculous agency can hardly be overlooked. Between the highest degree of certainty with which a fact can be invested by evidence, and the faintest probability, there is room for every shade of assurance.

Now it is notorious both that different minds are differently affected by the same evidence, and that some minds seem peculiarly constituted by nature to admit the full force of one mode of proof, whilst they are comparatively insensible to another; so that it might happen that whilst to one inquirer the testimony which supported the story of the miraculous facts seemed so strong as to supersede the necessity of confirming his belief in the revelation by the evidence which the matter of it might supply, and which perhaps he might be little able to appreciate, another might rather feel that the miracles were so far proved as to complete the satisfaction which he had already derived from the other source.

The Christian revelation, which may be considered as forming one subject with the Jewish, from the wide field over which it is spread and the miscellaneous character of its contents, must necessarily supply, in large abundance, matter for examination in the way of evidence. An enumeration, which however does not pretend even to approach completeness, of the constituent parts of the body of evidence belonging to it, together with the proper mode of using them and estimating their joint force, may be found shortly but very clearly proposed in the first of Mr. Davison's 'Discourses on Prophecy.' Before we leave this part of the subject, we would observe, what seems sometimes to be overlooked, that an action may itself be a revelation. It would not be improper to say that the birth, death, and actions, even more than the discourses of Jesus Christ, were a revelation, of which the Apostles, who taught what are called the doctrines of Christianity, were only the interpreters. Of these doctrines it is not our business to treat, but we will select one as the subject of a few observations, merely with a view to illustrate the disposition of mind with which we must necessarily regard the pretensions and evidences of a professed revelation, according as we recognise, or not, a need which men have of extraordinary information on the subject of religion. The doctrine we select is that of the immortality of the soul and a future state of rewards and punishments. Without assuming the probability or improbability of this doctrine, we suppose it to be notorious that the immortality of the soul, or some kind of continued existence after bodily death, with liability to a state of happiness or suffering, has been very generally believed, in one shape or other, in all parts and at all periods of the world; and that this doctrine is distinctly delivered and prominently set forth in the New Testament. There is as little doubt that before the time of Christianity, either the notions commonly received of a future state were so irrational, or the belief of it so faint and unassured, that for the most part it had comparatively little effect on the moral feelings and conduct of men; and that on the other hand, wherever the Christian revelation has been published, this doctrine has not only been firmly received with little variation in the manner of understanding it, but has influenced the conduct of many, happily or not, in the most important respects, and regulated the whole course of their lives. It is plain that those who regarded the distinct and authoritative announcement of this doctrine to be among the things especially needed by mankind, and those who considered it to be either useless or mischievous, would be very differently impressed by the general body of evidence in favour of the revelation.

Among professed revelations which have been the ground of a national religion, it may be doubtful whether we should place the mythological systems of ancient Greece and Rome. They are indeed avowedly founded on traditional accounts of certain transactions between gods and men; but from the nature of the transactions, of the supernatural beings concerned in them, and the purposes of the interference, we may doubt whether the discoveries supposed to be made belong to the notion of a revelation according to our definition of the word, or the usual acceptation of it. The same for the most part may be said of the mythology of the Hindus and of the northern nations of Europe. But there can be no doubt that the religion of Mohammed, as taught in the Korán, professes to be founded on a revelation in the strict sense of the word, such as may be subjected to the same tests which we have supposed to be applicable to all revelations.

In passing from the Christian revelation itself to the written record of it, a new and important question is opened to us. The revelation may have been made to the persons who profess to have received it; but in recording it also, were they preternaturally assisted, or were they left to the use of their natural memories, and the guidance of their unassisted judgment? In other words, we are met by a question respecting what is called the inspiration of the books of Scripture, or, more properly, of the persons who wrote them. By this word we are to understand, not the preternatural infusion of revealed truths into the minds of the writers (which however would not be inconsistent with the original meaning of the word), but preternatural assistance in recording what had been so infused. This distinction should be observed. St. Paul, if we believe his own declaration, received immediately from God a message to men. He may be supposed to have delivered this message orally or in writing to others from memory; and in that case he would have been a deliverer and they receivers, in the strictest sense of the words, of a divine revelation; but the message, so delivered, would not in theological language have been an inspired message, that is, spoken or written under inspiration. It is beside our purpose to defend or impugn the doctrine of the inspiration of Scripture generally, or, out of the various theories which have been put forth, to advocate one in preference to the others. We only wish to do something towards clearing away certain fears and difficulties, which seem to beset and mislead many in the very outset of the inquiry, and to offer a few suggestions as to the principle on which the inquiry should be conducted, to those who are not very conversant with the subject.

In the case of most persons educated in the Christian faith, their first introduction to the Bible is accompanied by an assurance that it was dictated by God, and is *therefore* true; and this is told them at a time when its claims, as an authentic history, independently of its inspiration, neither are nor can be explained to them. This early impression, perhaps unavoidable, that the Scriptures are to be received as true, *only* because they are the Word of God, is probably retained for the most part without question, in spite of its inconsistency with the method and object of books which are given, almost as universally as the Bible, to all educated persons for the purpose of establishing their faith on rational grounds. Hence they are habituated from the very nursery to confound in their minds two questions essentially distinct, the divine origin of the Christian religion, and the divine origin of the scriptural records of it. All might easily remove this confusion by simply answering the question, what would be the natural course of our inquiries, and by what steps should we arrive at conviction of the divine origin of the Christian religion, if the volume of the New Testament were for the first time put into our hands for examination, at an age when we were capable of making it? It is obvious that we should not begin with assuming the inspiration of the writers; for that would be assuming the very point in debate, assuming that for which we had not as yet a shadow of evidence. But neither is it of their inspiration that it would be our first object to find evidence; for such evidence could not at first be obtained. If we ever came to the conclusion that they were inspired, it must be because either the very supposition of a revelation from God included in it the supposition of a revelation on the part of those who communicated it, or because all the writers themselves claimed inspiration, or some, whose claims we had already allowed, attributed it to the rest. In the former case we must *first* have believed that a revelation was made; in other words, that the origin of the religion was divine: in the other, if we assent to the claim of inspiration, we must *first* have admitted the credibility, the veracity of those who make it; that is, if we believe them to be inspired because they say so, we must have had reason for believing what they say, on other ground than that of their inspiration. It seems then that it would be our first object to establish, not the inspiration, but the credibility of the sacred writers apart from their inspiration. We should proceed from the establishment of their credibility, to inquire, in the second place, if they were inspired. The result, in short, to which we have actually come is this: the New Testament is put into our hands for examination, and we find that the claims of Jesus and his followers to a divine commission rest on the miracles which they are said to have performed. Our belief of the fact of the miracles depends on the credit we attach to the story of the witnesses. If that is substantially true, Jesus came from God. With the arguments by which the credibility of the gospel history is proved we have here no concern. It is plain that it is not proved by the inspiration of the authors. Some confusion seems to have arisen from a strange mistake respecting the kind of satisfaction which the inspiration of the sacred writers, when established, is capable of supplying. It does not confirm their veracity, it only implies their accuracy. It secures us from their mistakes, not from their falsehood. Now if it should be argued that without inspiration we can have no assurance that they were not mistaken, when they tell us that they saw a man dead on the cross, laid in his grave, and afterwards alive, it may be asked, how can they be secured from their liability to mistake, when they tell us that they are inspired? It is at least as likely that they should be mistaken in the one case as in the other. The obvious truth is, that if we cannot rely on their veracity when they vouch for miracles, we can trust none of their assertions, and admit none of their claims; and if they might be mistaken as to the fact of a miracle, they might be equally mistaken in their claim of inspiration for themselves or for others.

It is hardly necessary to observe that the various methods followed by writers on the evidences of the Christian religion are all in conformity with the view that has been taken of this subject. They endeavour to show the genuineness and authenticity of the books of the New Testament, the fidelity, disinterestedness, and integrity of the writers; to point out their means of information as human historians, and to confirm the accuracy of their accounts by comparison with other records. The question of inspiration forms no part of their inquiry. It is beside their object, which is to prove the divine origin of Christianity; and this is fully proved if their arguments are satisfactory.

It is not meant, of course, that all who are brought to a conviction of the truth of Christianity, arrive at it in the same manner. It is sufficient for our argument that it may be reached in the manner we have supposed. In short, on whatever support the believer himself may eventually feel that his faith habitually reposes, if he should ever be impelled by any motive to trace his conviction to a source from which it can be shown to others by reasoning that it may legitimately flow, he will find that he must rely, in the first instance, on the credibility of the sacred writers, however established, considered as uninspired historians. With this foundation laid, he may commence an inquiry into the proofs of their inspiration; and he may pursue it with a full assurance that to whatever result it may lead, the divine origin of his religion is already secured; that he has in possession a revelation from God, truths divinely communicated to men. We may seem to have taken unnecessary pains to establish a point too plain to be disputed. Our justification must be, that it does not seem to have been so plain to some even of those who have written on the subject, and are occasionally quoted as authorities, and who have been led, apparently by the confusion which we deprecate, into unwarrantable insinuations of infidelity against those who differ from them in opinion.

If the question should be asked, where, when the divine origin of the religion is supposed to be established on the credibility of the sacred writers, we should look for proof that the books which are the records of it were written under the security of inspiration? the natural answer would be that it must be looked for in the books themselves, from the claims, declarations, and intimations of the writers. When, for example, one of the evangelists has recorded a distinct promise made by their master to his Apostles, of a divine gift for the declared purpose of assisting the memory and enlightening the understanding, the inference seems to be unavoidable that those to whom the promise was given must have written with more than natural advantages. The argument founded on the necessity of inspiration to render the sacred books effectual for the purpose for which they were intended, ought not perhaps to be slighted. We have seen indeed that the supposition of the divine origin of the religion does not necessarily require the admission of inspiration; yet the peculiar character of the contents of the books, together with the service they were destined to perform, may raise a presumption in its favour. The direct testimony however from the writers themselves must be principally regarded. But when commencing the examination, whilst the evidence is yet to be found, we must be careful to estimate correctly the degree of authority which ought in this stage of the inquiry to be attributed to the words of Scripture. They are not yet proved to be the words of God. The declarations of the writers must be received and interpreted fairly and liberally, as the solemn declarations on a solemn subject, of honest and credible writers, ought to be received and interpreted. If the evidence which we seek to obtain from them cannot be obtained in this manner, it cannot be obtained at all. To search Scripture for proofs of its inspiration whilst at the same time we assume it to be inspired, is a proceeding so obviously absurd, that if experience did not teach us otherwise, any caution against it would seem to be unnecessary. But even when this strange error is not committed, declarations of the sacred writers, apparently bearing on this subject, may be and often are improperly summoned to the cause. When a writer professes to have received secret suggestions from the deity, that is, to be the subject of inspiration in one sense of the word, he is represented as claiming it in the other, as though the privilege of receiving communications necessarily implied the privilege of infallibility in recording them. This confusion has been noticed on another occasion.

That most popular argument for the inspiration of a particular book, founded on testimony borne to the purity and integrity of the canon of Scripture, may be soon disposed of. When it has been proved that a book forms part of what is called the canon, it may follow that it forms part of Scripture. This will not carry us far when the question to be decided is, what are the claims of Scripture to inspiration?

There is one mode of proof, besides those already mentioned, which ought perhaps to be noticed, as being much in favour with some theologians, namely, an appeal to what is called the tradition of the church. There are some advocates of inspiration, in the strictest sense and most unlimited application of the term, who allow, or rather contend, that the proof of it rests mainly, if not entirely, on the testimony of tradition. An examination of the value of this testimony would oblige us to enter more largely, than would here be expedient, on the important question of ecclesiastical tradition generally. We shall content ourselves with saying that, in this case at least, we greatly doubt, for many reasons, the sufficiency of the witness, and are not satisfied, even where it speaks to the purpose, that its words have always been rightly understood. However this may be, it is plain that the mode of proof also supposes the question of the divine origin of the Christian religion to be independent and to have precedence of the question of inspiration.

We shall close this article with a brief notice of the three most popular theories of inspiration, which are distinguished from each other more in respect of the extent to which they attribute inspiration, than in respect of any difference in the meaning assigned to the word.

That which is called verbal inspiration supposes each word in the Bible, as we now have it, with due allowance made for mistakes of transcribers, to have been irresistibly dictated by the Spirit of God, the writers being only vehicles of words and thoughts not their own. This notion of inspiration has undoubtedly still its advocates; but we are not aware that it is at present maintained by any divine of repute. According to another theory, somewhat modifying the former, the writers were allowed to exercise their own judgment in the choice of their words; but in the meaning of each sentence, from the first verse of Genesis down to the last of the Revelations, they have been secured by supernatural interference from the least particle of error. This theory, which is not without support from well-known theologians, represents perhaps more nearly than any other the popular creed. Lastly, there are many, and amongst them divines of great eminence and reputed orthodoxy, and not a few distinguished prelates of the English church, who limit the extent of inspiration as commonly received, and suppose that parts of Scripture may have been written with the liability to error incident to ordinary histories; those for instance which are purely historical, and contain no religious truth. As to the degree in which this limitation is to be admitted, and the number and length of passages to be excepted from the sanction of inspiration, there is of course room for diversity of opinions, which affords apparent ground for objection to the theory itself. The advocates of the two former theories contend that a latitude for choice is allowed which is capable of a dangerous abuse. The truth of the allegation cannot be disputed; but perhaps it is not possible by any device to exclude the danger which alarms them. The canon of Scripture has not been ascertained to us by an authoritative revelation, nor has the purity of the text been absolutely secured by providential interference. A liberty is thus left, which in these cases also may become dangerous to those who are willing to abuse it. Some however may think that the test of sincerity and right intention, and the means of probationary discipline which the allowance of such a measure of discretion affords, is apparently in harmony with what we have been taught of God's moral government of the world. On the other hand it is objected to the advocates of the more rigid theories, that the faith of the believer is exposed to still greater danger by the forced constructions and violent treatment of the text which their systems have often induced them to employ.

It might perhaps have been expected that we should notice a certain classification of the phenomena of inspiration of which many theologians are fond, certain distinctions in kind, under the titles of impulsive, suggestive, superintending, and many others. The truth is, we think them to be of very little value on any view of the subject. They seem to have been adopted by theologians who hold the theory of plenary but not verbal inspiration, from a wish to remove the necessity of supposing a greater quantity or degree of miraculous agency than the occasion required.

We have drawn none of our materials from the writings of a class of theologians who, regarding the Scriptures as in some sense, not very clearly defined, vehicles of religious truth, exclude all notion of revelation which is not equally applicable to discoveries made by human intelligence, and who give no credit to assertions of miraculous interposition, whether in conveying knowledge or attesting facts. Whatever consideration may be due to the writers, some of whom are men of ingenuity and research, their speculations could hardly have an appropriate place in treating of the subjects to which this article is confined. [RATIONALISM.]

REVELATIONS, BOOK OF. [APOCALYPSE.]

REVELS, MASTER OF THE, an officer in noblemen's and other great houses, appointed *pro tempore* to manage the Christmas diversions from All-hallow-eve to Candlemas-day: more ordinarily called the *Lord of Misrule*. In the royal household however the master of the revels was a permanent officer, and was called Master of the Tents and Revels or Masks and Revels, whose business it was to keep the tents and pavilions belonging to the king, which were often, if not always, carried with the king upon removes and progresses. This officer had also the keeping of the dresses and masks which were used in entertainments given at court, and he was to provide such new ones as were wanted.

The permanent office of master of the revels was first instituted in the reign of Henry VIII. Queen Elizabeth divided the mastership of the revels into several offices, which, as vacated by death, were to be re-united. In 1663 we find two masters of the toils, tents, hayles, (that is, halls or temporary buildings), and pavilions, who again occur in 1674.

See the 'Archæologia,' vol. xviii. p. 318, &c., and 'The Loseley Manuscripts,' edited by A. J. Kempe, Esq., 8vo., Lond., 1836. No mention of this office has been found subsequently to the reign of king Charles II.

REVERSION. By a reversion, in the widest sense, is meant a right of property the enjoyment of which is to commence at some future period, fixed or depending on contingencies, and is to continue either for ever or during a term either fixed or depending on a contingency: anything in fact which is to be entered on, or which may be entered on, at a future time, is a reversion in books which treat on the value of property. The legal sense of the word is more restricted.

Thus an assurance of 100*l.*, or a contract to pay 100*l.* at the death of a given individual, is 100*l.* in reversion to the executors of that individual. Our object in this article is to treat of this most common species of reversionary contract, life insurance or assurance.

The value of a reversion depends in a very easy manner upon the value of the corresponding annuity; that is, any given sum, say 100*l.*, to be received *when* a given event arrives, depends for its value upon that of 100*l.* a-year to be received *till* the event arrives. Suppose, for example, that money makes five per cent., and that an annuity, say upon a life, is worth fourteen years' purchase, upon the method of calculation explained in ANNUITY. That is, 100*l.* paid a year hence, and again two years hence, and so on as long as the life lasts, is now worth 1400*l.* Required the value of 100*l.* to be paid at the end of the year* in which the life drops. We must now reason as follows:—Suppose a perpetual annuity of 100*l.* a-year is to be enjoyed by A during his life, and by his legatees after him. By hypothesis A's portion is now worth 1400*l.*, and (money making five per cent.) the annuity for ever is worth 20 years' purchase, or 2000*l*; consequently the legatees' interest is *now* worth 2000—1400, or 600*l*. But at the end of the year of death the legatee will come into 100*l.* current payment, and a perpetual annuity worth 2000*l.*; for the remainder of a perpetual annuity is also a perpetual annuity: his interest will *then* be worth 2100*l.* Hence we have ascertained that 2100*l.* at the end of the year of death is now worth 600*l.*; and the rule of three then gives the value of any other sum: thus 100*l.* at the end of the year of death is now worth $\frac{600}{21}$*l.*, or 28*l.* 11*s.* 5$\frac{1}{7}$*d.* Hence the following easy

RULE.—To find the value of a given reversion, subtract the value of the same annuity from that of a perpetual annuity, and divide the difference by one more than the number of years' purchase in a perpetual annuity: or multiply the excess of the number of years' purchase in a perpetual annuity of 1*l.* over that in the life annuity by the reversionary sum, and divide as before.

Next, to find what premium should be paid for the reversion. A premium differs from an annuity in that a sum is paid down, and also at the end of every year: consequently it is worth one year's purchase more than an annuity. In the preceding question, the annuity was worth 14 years' purchase; consequently the premium now is worth 15 years' purchase. But the present value of all the premiums is to be also the present value of the reversion, or 28*l.* 11*s.* 5$\frac{1}{7}$*d.*, whence the premium should be the 15th part of this, or 1*l.* 18*s.* 1*d.* Hence to find the premium, divide the present value of the reversion by one more than the number of years' purchase in the life annuity. But when, as most commonly happens, the premium is wanted without the present value, the following is an easier

RULE.—Divide the reversionary sum separately by one more than the number of years' purchase in the perpetual annuity, and one more than the number of years' purchase in the life annuity: the difference of the quotients is the premium required. Thus if in the preceding example we divide 100*l.* by 20 + 1 and by 14 + 1, or by 21 and 15, we find 4*l.* 15*s.* 3*d.* and 6*l.* 13*s.* 4*d.*, which differ by 1*l.* 18*s.* 1*d.*, the same as before.

The life we have been tacitly considering, when we talked of an annuity being worth 14 years' purchase at five per cent., is one of about 36 years of age. The first impression must be, that the proposed premium is ridiculously small. Make it up to 2*l.*, and it will be 50 years before the premiums reach 100*l.* Some such consideration must have moved the law officers of the crown, in 1760, when they refused a charter to the Equitable Society, then charging a premium of about 4*l.* at the age of 36, on account of the lowness of their terms. But it is to be remembered that those who receive the premiums are to invest them immediately at five per cent., and are to invest the interest, thus making compound interest; persons aged 36 live, one with another, about 30 years, which is sufficient time for the premiums, with their interest, to realize 100*l.* for each person, one with another.

We now show the manner in which a simple result of calculation answers its end. To simplify the case, suppose an office starts with 5642 individual subscribers, each aged 30 years, the mortality among them being that of the Carlisle Table. [MORTALITY.] The bargain is for a temporary assurance, as it is called, of 20 years, and of 1000*l.*: that is to say, the executors of each one who dies within 20 years are to receive 1000*l.* at the end of the year of death. Money makes three per cent. once a year. According to the table, then, there are 57, 57, 56, &c. deaths in the successive years, and the following is the result, the proper premium being calculated at 11*l.* 12*s.* 3½*d.* each person, or more exactly 11,614*l.* 16*s.* for 1000 persons. It is supposed that there are no expenses of management. By P is meant that premiums are paid, and the number paid precedes the letter: by *y*, that a year's interest is received, and by *c*, that claims, in number as stated, are paid; small letters denote a transaction at the end of a year, and the large letter one at the beginning; the age of the parties paying premiums is in parentheses at the beginning. Fractions of pounds are neglected, 1*l.* being written for everything above 10*s.*

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* Assurance companies usually pay in a few months after proof of death, which gives a trifling advantage to the assured, not worth considering in a very elementary statement of the question.

		£
(30)	5642 P	65530
	y	1966
		67496
	57 *c*	57000
		10496
(31)	5585 P	64869
		75365
	y	2261
		77626
	57 *c*	57000
	+	20626
(32)	5528 P	64207
		84833
	y	2545
		87378
	56 *c*	56000
	+	31378
(33)	5472 P	63557
		94935
	y	2848
		97783
	55 *c*	55000
	+	42783
(34)	5417 P	62917
		105700
	y	3171
		108871
	55 *c*	55000
	+	53871
(35)	5362 P	62279
		116150
	y	3485
		119635
	55 *c*	55000
	+	64635
(36)	5307 P	61640
		126275
	y	3788
		130063
	56 *c*	56000
	+	74063
(37)	5251 P	60989
		135052
	y	4052
		139104
	57 *c*	57000
	+	82104
(38)	5194 P	60327
		142431

		£
	Brought over	142431
	y	4273
		146704
	58 *c*	58000
	+	88704
(39)	5136 P	59654
		148358
	y	4451
		152809
	61 *c*	61000
	+	91809
(40)	5075 P	58946
		150755
	y	4523
		155278
	66 *c*	66000
	−	89278
(41)	5009 P	58179
		147457
	y	4424
		151881
	69 *c*	69000
	−	82881
(42)	4940 P	57378
		140259
	y	4208
		144467
	71 *c*	71000
	−	73467
(43)	4869 P	56553
		130020
	y	3901
		133921
	71 *c*	71000
	−	62921
(44)	4798 P	55729
		118650
	y	3560
		122210
	71 *c*	71000
	−	51210
(45)	4727 P	54904
		106114
	y	3183
		109297
	70 *c*	70000
	−	39297
(46)	4657 P	54090
		93387

		£
	Brought over	93387
	y	2801
		96188
	69 *c*	69000
	−	27188
(47)	4588 P	53288
		80476
	y	2414
		82890
	67 *c*	67000
	−	15890
(48)	4521 P	52510
		68400

		£
	Brought over	68400
	y	2052
		70452
	63 *c*	63000
	−	7452
(49)	4458 P	51779
		59231
	y	1777
		61008
	61 *c*	61000
		8

At the outset the office receives 65,530*l.* from the 5642 persons assured; this is immediately invested at 3 per cent., and yields 1966*l.* by the end of the year, making 67,496*l.* But at the end of the year the claims of the executors of 57 persons who have died during the year are to be satisfied, which requires a disbursement of 57,000*l.*, reducing the society's accumulation to 10,496*l.* The contributors who are left, 5585 in number, now pay their second premiums, 64,869*l.*, so that, these being immediately invested, the company has 75,365*l.* at interest during the second year. This yields 2261*l.*, so that by the end of the year 77,626*l.* is accumulated. Then comes the demand of 57,000*l.* on behalf of 57 contributors deceased during the year, which reduces the accumulation to 20,626*l.* This is more than it was at the same time last year, which is denoted by +. In this way the company goes on, accumulating to an amount which would lead a person unacquainted with the subject to conclude that the premium must be too large: in fact ten years give an accumulation of 91,809*l.* But now the state of affairs begins to change; the contributors have been diminishing, while the claims have been increasing, until the yearly incomings no longer equal the outgoings. The accumulations then come in to make good the difference in such manner that by the time the remaining contributors come to be 50 years of age, and the claims of 61 who died in their fiftieth year have been satisfied, there only remains 8*l.* of the 91,809*l.*; and this 8*l.* is merely the error arising from omitting shillings, &c., in the calculation. Something of the same kind must take place in every office which dies a natural and a solvent death: the only difference being that, when new business ceases, instead of a number of contributors all of the same age, and under similar contracts, both ages and contracts vary considerably.

There are certain tables which are variously named (sometimes after Mr. Barrett, the inventor; sometimes after Mr. Griffith Davies, the improver; sometimes after D and N, letters of reference used in them), but which we call commutation tables. They are described in the 'Treatise on Annuities,' in the 'Library of Useful Knowledge,' and a copious collection is given: also in an article in the 'Companion to the Almanac' for 1840. They very much exceed in utility those which preceded them; and we shall here give part of one of them, namely, that for the Carlisle Table, at 3 per cent., which contains the materials for judging of the demands made by an insurance company in cases involving one life only. Opposite to each age of life are three rows of figures in columns marked D, N, and M; and by M (*x*) we mean the number in column M opposite to the age *x*.

Age.	D.	N.	M.	Age.
0	10000·00	173198·26	4664·129	0
1	8214·56	164983·70	3169·954	1
2	7332·45	157651·25	2527·103	2
3	6656·74	150994·51	2064·957	3
4	6217·63	144776·88	1819·735	4
5	5863·15	138913·73	1646·351	5
6	5591·04	133322·69	1545·0149	6
7	5361·53	127961·16	1478·3414	7
8	5159·58	122801·58	1432·5557	8
9	4976·34	117825·24	1399·5998	9
10	4806·85	113018·39	1375·0447	10
11	4645·89	108372·50	1354·0945	11
12	4488·83	103883·67	1332·3517	12
13	4336·30	99547·37	1310·5613	13
14	4188·18	95359·19	1288·7444	14
15	4043·73	91315·46	1266·2792	15
16	3901·65	87413·81	1241·9757	16
17	3762·60	83651·21	1216·5650	17
18	3627·75	80023·46	1191·3070	18

Age.	D.	N.	M.	Age.
19	3497·36	76525·90	1166·7847	19
20	3371·89	73154·01	1142·9766	20
21	3250·56	69903·45	1119·8620	21
22	3133·96	66769·49	1097·9425	22
23	3021·40	63748·09	1076·6614	23
24	2912·74	60835·35	1056·0001	24
25	2807·54	58027·81	1035·9408	25
26	2706·42	55321·39	1016·0019	26
27	2607·95	52713·44	996·6438	27
28	2512·32	50201·12	976·9753	28
29	2417·93	47783·19	955·7530	29
30	2324·43	45458·76	932·6867	30
31	2233·93	43224·83	909·8874	31
32	2146·73	41078·10	887·7522	32
33	2063·09	39015·01	866·6387	33
34	1982·87	37032·14	846·5062	34
35	1905·57	35126·57	826·9601	35
36	1831·09	33295·48	807·9833	36
37	1759·00	31536·48	789·2243	37
38	1689·22	29847·26	770·6864	38
39	1621·71	28225·55	752·3727	39
40	1555·78	26669·77	733·6727	40
41	1490·82	25178·95	714·0293	41
42	1427·46	23751·49	694·6911	42
43	1365·96	22385·53	674·1726	43
44	1306·84	21078·69	654·8342	44
45	1250·00	19828·69	636·0591	45
46	1195·62	18633·07	618·0875	46
47	1143·60	17489·47	600·8886	47
48	1094·08	16395·39	584·6747	48
49	1047·41	15347·98	569·8728	49
50	1002·99	14344·99	555·9583	50
51	960·707	13384·278	542·8920	51
52	919·395	12464·883	529·5612	52
53	879·047	11585·836	515·9924	53
54	839·663	10746·173	502·2108	54
55	801·433	9944·740	488·4371	55
56	764·144	9180·596	474·4915	56
57	727·792	8452·804	460·3956	57
58	691·828	7760·976	445·6299	58
59	655·419	7105·557	429·3712	59
60	618·338	6487·219	411·3795	60
61	580·223	5906·996	391·2752	61
62	543·165	5363·831	371·1105	62
63	507·618	4856·213	351·3896	63
64	473·982	4382·231	332·5369	64
65	441·875	3940·356	314·2372	65
66	411·379	3528·977	296·6107	66
67	382·422	3146·555	279·6357	67
68	354·803	2791·752	263·1551	68
69	328·468	2463·284	247·1545	69
70	303·240	2160·044	231·4936	70
71	279·203	1880·841	216·2889	71
72	255·119	1625·722	200·3366	72
73	230·813	1394·909	183·4619	73
74	206·585	1188·324	165·9566	74
75	182·483	1005·841	147·8717	75
76	160·245	845·596	130·9482	76
77	139·558	706·038	114·9284	77
78	120·936	585·102	100·3722	78
79	104·637	480·465	87·5951	79
80	89·5602	390·9053	75·5660	80
81	76·3678	314·5375	64·98221	81
82	64·2223	250·3152	55·06098	82
83	53·5795	196·7357	46·28874	83
84	44·1701	152·5656	38·43998	84
85	36·0741	116·4915	31·68048	85
86	28·8845	87·6070	25·49154	86
87	22·6179	64·9891	20·06629	87
88	17·2112	47·7779	15·31836	88
89	13·0366	34·7413	11·64505	89
90	9·92975	24·81154	8·91787	90

Age.	D.	N.	M.	Age.
91	7·12856	17·68298	6·40590	91
92	4·94352	12·73946	4·42849	92
93	3·45567	9·28379	3·084616	93
94	2·48520	6·79859	2·214797	94
95	1·80961	4·98898	1·611594	95
96	1·34696	3·64202	1·201650	96
97	1·02344	2·61858	·917362	97
98	·772823	1·845761	·696555	98
99	·589532	1·256229	·535773	99
100	·468295	·787934	·431707	100
101	·353621	·434313	·330672	101
102	·245230	·189083	·232580	102
103	·142852	·046231	·137345	103
104	·046231	·000000	·044884	104

To find the value of an annuity of 1*l.* on a life of any age, divide the N of that age by its D. Thus at the age of 35 the value of an annuity of 1*l.* is N(35) ÷ D(35), or 35126·57 ÷ 1905·57, or 18·433*l.*, or 18*l.* 8*s.* 8*d.* Thus, the following formulæ will be readily understood:—

Value of an annuity which is to commence immediately; that is, which is to make the first payment in a year (age x) . .	$\frac{N(x)}{D(x)}$
Value of an annuity which is to commence in n years; that is, to make the first payment in $n+1$ years, if the party be then alive (present age x) . . .	$\frac{N(x+n)}{D(x)}$
Premium for such an annuity, payable now and n times in all	$\frac{N(x+n)}{N(x-1)-N(x+n-1)}$
The same premium, payable $n+1$ times .	$\frac{N(x+n)}{N(x-1)-N(x+n)}$
Value of a life annuity for n years; or payable n times at most . . .	$\frac{N(x)-N(x+n)}{D(x)}$
Present value of an assurance of 1*l.* at death	$\frac{M(x)}{D(x)}$
Premium for the same	$\frac{M(x)}{N(x-1)}$
Present value of an assurance of 1*l.* at death if after n years	$\frac{M(x+n)}{D(x)}$
Premium for the same, payable $(n+1)$ times	$\frac{M(x+n)}{N(x-1)-N(x+n)}$
Present value of an assurance of 1*l.* at death if within n years	$\frac{M(x)-M(x+n)}{D(x)}$
Premium for the same, payable n times .	$\frac{M(x)-M(x+n)}{N(x-1)-N(x+n-1)}$

As an instance, let us take the case of the last formula, which was proposed at the beginning of this article: the age is 30, and the term of insurance 20 years; we have then to divide the excess of M (30) over M (50) by the excess of N (29) over N (49):—

M (30)	932·6867	N (29)	48783·19
M (50)	555·9583	N (49)	15347·98
	376·7284	div. by 32435·21 gives ·0116148:	

this is for 1*l.*, giving 11·6148*l.*, or 11*l.* 12*s.* 3½*d.* for 1000*l.*, and 11,614·8*l.* to be the total premium for 1000 persons.

Question.—If the office insure a large number of persons (for the whole life or a term) at the premium p (the age being x), what will be their accumulation in n years, upon the suppositions the working of which has been shown in the example already given; it being supposed that £A is insured to every one who dies? The answer is in the following formula: for every person who, according to the tables, is alive at the end of the term of n years, there is remaining in the office, after all claims have been paid up to the end of the n years, and before the $(n+1)$th premium is paid, the sum

$$\frac{p\,\{N(x-1)-N(x+n-1)\}-A\,\{M(x)-M(x+n)\}}{D(x+n)}$$

As an example we shall verify the accumulations of 10 years in the instance referred to; in which $p = 11·6148l.$, $A = 1000l.$, $x = 30$, $n = 10$.

```
         N(29) 47783·19          M(30) 932·6867
         N(39) 28225·55          M(40) 733·6727
               --------                --------
               19557·64                199·0140
             × 11·6148                 × 1000
               --------                --------
               227158·1                199014·0
               199014·0
               --------
                28144·1
      D(40)       1555·78)28144·1(18·09002
                                   × 5075
                                   --------
                                   91806·84
```

The answer is, that the reserve of premiums for each person of the 5075 then remaining is 18·09002*l.*, which for the whole is 91806·84*l.* The rough answer in the scheme worked out at length is 91,809*l.*

Now, this 18·09*l.*, or 18*l.* 1*s.* 10*d.*, is what is called the value of each man's policy at the expiration of the ten years; or the *very utmost* the office could afford to give him to surrender all claim, and to keep his future premiums to himself. But what is the nature of his claim on the office? Evidently this, that he has a right to make them give him a guarantee for the next ten years on payment of a premium of 11*l.* 12*s.* 3½*d.*, which could not be done at so low a rate for a new comer. Compute the premium for a person entering at 40, and insuring 1000*l.* for 10 years; or divide 1000 times M(40)−M(50) by N(39)−N(49), and the answer will be found to be 13·800*l.*, or 13*l.* 16*s.* If then any person aged 40, having been in the office ten years, were to put another person of the same age in his place at his own premium, he would obviously make that person a present of the difference between 11·6148*l.* and 13·800*l.*, at once (since a premium is to be paid immediately), and for nine succeeding years, if the latter should live so long. And 13·800−11·6148 is 2·1852, while an annuity of 2·1852*l.* for nine years, at the age of 40, is worth N(40)−N(49) divided by D(40) and multiplied by 2·1852, or 15·903*l.* Add to this 2·185*l.* for the immediate difference, and we get 18·088*l.*, differing only a halfpenny from 18·090*l.*, the sum which the office has in reserve. If then the person who is to take the place of the insured at 40 years of age, were to pay him an equivalent, he must, besides taking on himself the future premiums, pay the retiring member 18·090*l.*, which is therefore the value of the latter's policy. The last formula will always give the *accumulation* value of a policy, whether for the whole life or for a fixed term.

The preceding contains the most material calculations which are necessary in the management of an office, or rather, in forming an opinion on the management of an office. It is to be remembered that all which has hitherto been said supposes the rates of mortality and interest to be absolutely known and invariable, the parties to enter on their birthdays, and all claims to be adjusted at the terminations of whole years from the time of entry. We now proceed to the application.

An assurance company is a savings' bank, with a mutual understanding, presently to be noticed, between the contributors. To make out this proposition, let us suppose that A borrows money, and insures his life for the amount as a security to his creditor. For this he has to pay a premium. If life were certain, the office of the company would be to receive and invest these premiums, which would be calculated in such a manner as with their interest to amount to a sum sufficient to discharge the loan in a settled time. At the end of this time the creditor (who has been all this while receiving interest for his money from A) calls upon A to make his claim upon the office, and repay the loan with the money received. If such an office existed, life being certain, the rationale of the proceeding would be that the creditor, though tolerably confident of A's power and willingness to make any yearly payment, whether of interest or instalment, will not trust him steadily to lay by and improve yearly instalments, but requires that he should make his instalments payable to third parties, who are engaged not to return them on demand until they amount to a sum sufficient for the discharge of the debt. Such an office certainly could not exist, on account of the uncertainty of individual life. So soon however as it is known that the duration of masses of individuals can be calculated with tolerable accuracy, there is a remedy for the individual uncertainties. Let a large number of debtors, similarly situated with A, agree to be guarantees for one another; that is, let each of them pay during his life not only his own instalments, but such additional sums as will provide the means of meeting the deficits of those who die, and the savings' bank thus constructed will become an assurance office. Of course it matters nothing whether these debtors pay their instalments to a person agreed on among themselves, or go to a company which undertakes the management of such concerns. And again, it makes no difference whether the instalments be for liquidation of debt, or to accumulate a provision for widows and children. We have taken the case of debtors, because in such a case an office looks more like a mere indemnity-office than when its contributors enter for the benefit of their families; still however, in the former case, it is evident that the premiums are partly instalments of debt, partly sums intended to make good the deficiency of the life-instalments of those who die.

Let us now suppose a company to be formed for the simple purpose of assuring lives. Their business is to invest the premiums of those who assure with them; their receipts will consist entirely of current premiums and interest on the investments of the old ones; and their outgoings will contain expenses of management, payment of claims, purchase of their own policies, and (possibly) losses by bad investment.

There is one question which is generally settled at the very outset, namely, whether the company is to be what is called mutual, proprietary, or mixed.

A mutual company is one in which the members stand bound to each other, and constitute the company themselves. In such a company no capital is, generally speaking, raised at the outset, except a small sum for necessary expenses at starting. This however is not necessarily the feature of a mutual company; for if its members choose to constitute themselves an investment company as well as an assurance company, they may, without losing their *mutual* character, require every assurer to be also a shareholder. In a mutual company the profits of course are divided among the assured.

A proprietary company is one in which a body of proprietors raise a capital and pledge it for the payment of claims, in case the premiums are not sufficient: for this security they receive, in addition to the interest of their own capital, the profits of the assurance business. It has long been proved that, with proper tables of premiums, and a fair amount of business at starting, this capital is an unnecessary security; and the only reason which could now make such an office desirable, would be the lowness of its premiums. Of course it matters nothing to the assured how claims are paid, as long as they *are* paid; the capital may be diminished, but the assurer fears nothing except its exhaustion before his turn comes. This must be the sole consideration with a person who is tempted by low premiums to a purely proprietary office: the nominal capital signifies nothing; it is upon the amount of assurance to which it (with the premiums) is pledged that the solvency of the office depends. Generally speaking however we believe it will be found that the purely proprietary offices have not allowed themselves to run much risk.

A mixed office is one in which there is a proprietary company, which does not take all the profits, but a share; the rest being divided among the assured. The only good effect of the capital upon the condition of the assured in such a company is this; that the directors, having fixed capital as well as premiums, may justifiably seek for investments which a mutual company must avoid. Having the capital to make good purely commercial losses, they may perhaps attempt to get a higher rate of interest, and of course take more risk of loss; the assured, who are sharers in the whole of the profits, since the profits of premiums and profits of original capital are not distinguished, come in for their share of the extra profits of the capital. But no such attempt at gaining higher interest by secondary securities should be made until a sum sufficient (with future premiums) to meet all claims is invested in the very safest securities which the state of society offers.

There is much confusion in the ideas of many persons about interest, arising from not distinguishing between interest and other returns. The following remarks may serve to explain our meaning:—

Interest is the return which is made for the use of money, when the owner entirely relinquishes its management, and believes he has undoubted security for its return. "Interest," says Mr. M'Culloch, "is nothing more than the net profit on capital." The same author goes on to say, "the rate of interest on each particular loan must of course vary according to the supposed solvency of the borrowers, or the degree of risk supposed to be incurred by the lender." But here the acute writer from whom we quote, after setting out with the accurate definition of the political economist, proceeds to use the word in the common sense, in which it is no longer the net profit of capital. For this variation in the rate of interest (so called), this addition for possible insolvency, is or is meant to be only as much as will make every debtor who does pay contribute towards the bad debts of those who do not. Nothing then is netted by the increase for suspicion of insolvency, in the long run, and one debt with another; so that, abiding by Mr. M'Culloch's definition of interest as the correct one, we should propose to call the additional sum debt-insurance. To this we must add, that when a person employs his own money, as in trade or manufactures, he also gains that additional return which a borrower counts upon reserving to himself after paying the interest (and debt-insurance, if any) to his creditor. This is neither interest nor debt-insurance, but is of the nature of salary, by which name it might be called. Perhaps it would be best to retain the term interest in its general loose signification, and to subdivide it, for accuracy, into pure interest or net profit, debt-insurance, and salary.

In the construction of a table of premiums, three points must be left to the judgment of the constructor, the rate of interest, the table of mortality, and the addition to be made for expenses of management and probable fluctuation, or discrepancy between the predictions of the table and the events which actually arrive. The third point would not arise if, as was once the case, the table of mortality made life much worse than the actually prevailing state of things shows it to be. Security against adverse fluctuation is thus taken in the choice of the tables; and this was done by the older offices, which chose the Northampton Table,—by the Equitable, for instance. (Compare the mean duration of life in the Northampton Table with that of the Equitable experience, in MORTALITY.) But we hold decidedly by the method of choosing a true table, and augmenting the premiums given by it as a safeguard against fluctuation; and for this reason, that wrong tables are usually unequally wrong, making different errors at different ages, and thus augmenting different real premiums by different percentages.

According to the Carlisle Table (which we prefer for the purpose), of 5642 persons alive at the age of 36, 3018 are alive at 65, whence the chance of living till the second age is 3018 ÷ 5642 or ·5525. Now, by applying calculation to this question, we find that an office which would have practical certainty (thousands to one for it) that, so far as this instance is concerned, the office should not be injured by adverse departure of events from tables, must make provision for twenty-five deaths, at least, in the period above-mentioned, more than the tables predict. And this even on the supposition that the table itself can be certainly reckoned upon as representing the law of mortality of the whole insurable population. It would be a very long process indeed to apply calculation in detail, so as to form a well-supported idea of the proper amount of precaution against fluctuation; and the question is mixed up with another, to which we proceed.

The rate of interest to be assumed is an element which requires the greatest caution. It must be a rate which can actually be made, and therefore prudence requires that it should be something below that which may reasonably be looked for. To show how powerful an agent it is, we shall repeat the example already given, of the 5642 insurers for twenty years, on the supposition that the office which charges as for 3 per cent. finds itself able to make 3½ per cent.

	£		£
(30) 5642 P	65530	Brought over	129203
y	2294	*y*	4522
	67824		133725
57 *c*	57000	56 *c*	56000
	10824	+	77725
(31) 5585 P	64869	(37) 5251 P	60989
	75693		138714
y	2649	*y*	4855
	78342		143569
57 *c*	57000	57 *c*	57000
+	21342	+	86569
(32) 5528 P	64207	(38) 5194 P	60327
	85549		146896
y	2994	*y*	5141
	88543		152037
56 *c*	56000	58 *c*	58000
+	32543	+	94037
(33) 5472 P	63557	(39) 5136 P	59654
	96100		153691
y	3364	*y*	5379
	99464		159070
55 *c*	55000	61 *c*	61000
+	44464	+	98070
(34) 5417 P	62917	(40) 5075 P	58946
	107381		157016
y	3758	*y*	5496
	111139		162512
55 *c*	55000	66 *c*	66000
+	56139	—	96512
(35) 5362 P	62279	(41) 5009 P	58179
	118418		154691
y	4145	*y*	5414
	122563		160105
55 *c*	55000	69 *c*	69000
+	67563	—	91105
(36) 5307 P	61640	(42) 4940 P	57378
	129203		148483

	£		£
Brought over	148483	Brought over	105442
y	5197	*y*	3690
	153680		109132
71 *c*	71000	69 *c*	69000
—	82680	—	40132
(43) 4869 P	56553	(47) 4588 P	53288
	139223		93420
y	4873	*y*	3270
	144106		96690
71 *c*	71000	67 *c*	67000
—	73106	—	29690
(44) 4798 P	55729	(48) 4521 P	52510
	128835		82200
y	4509	*y*	2877
	133344		85077
71 *c*	71000	63 *c*	63000
—	62344		22077
(45) 4727 P	54904	(49) 4458 P	51779
	117248		73856
y	4104	*y*	2585
	121352		76441
70 *c*	70000	61 *c*	61000
—	51352		15441
(46) 4657 P	54090		
	105442		

It thus appears that the office leaves off with an accumulation of 15,441*l*. nearly; and if it be lucky during the first years, it may be said to be safe (as we find) against any fluctuation for which there is an even chance, by the increase of interest alone.

Take what amount of precaution we may, an office must, at first starting, depend upon something either of capital or guarantee. Even a mutual office must raise something at the outset. Tables must be constructed with very large additions to the calculated premiums, which are to meet the very earliest contingencies alone; indeed it is difficult to say what addition would be too large. But this point it is unnecesary to insist on, since we can hardly suppose it possible that any set of men would found an office with no resource except premiums from the very commencement. Supposing proper precautions to be taken, we imagine that an addition of 25 per cent. to premiums calculated from the Carlisle Tables at 3 per cent. per annum, is sufficient to place a mutual office upon a sound footing, and to give a very great prospect of a return in the shape of what is called profit. It never has been found that an office charging at this rate has been without surplus of some kind.

This surplus has been called by the inaccurate name of profit, whereas it is really that part of the security against fluctuation of interest and mortality which has been found to be unnecessary. In mutual offices it is to be returned to the assured in an equitable manner; in purely proprietary offices it is really profit to the proprietors, whose capital has yielded them the ordinary interest, since by hypothesis none of it has been necessary to meet claims, and they therefore share among themselves the residue of the premiums. It is impossible to avoid this surplus in a well-constituted office, for the mathematical line which separates surplus from deficiency cannot be expected to be attained, so that those who would not have the latter must take care to have the former.

The questions connected with life assurance, &c., have become so many and so important that it is impossible to enter on the subject, with reference to the points actually discussed in our own day. The scientific reader will find in the pages of the 'Assurance Magazine,' materials for thought on most of these subjects. For others, we know of no work which gives so much information, and which so well enables the reader to refer all statements to their real sources, as an anonymous work, 'The Assurance Guide and Handbook,' London, 8vo, 1857 (published by W. S. D. Pateman, pp. 440). This work professes to be intended for insurance agents, and, so far as we can find, has no leaning to any particular offices or systems.

REVERSION OF SERIES. In the nomenclature of mathematics, which is far from being consistent with itself, the words *reversion* and *inversion* are sometimes confounded. Thus the term by which we describe the square root, as connected with the square, is, that each is an INVERSE process to the other; but if y be a given series of the powers of x, the determination of x in a series of functions of y is not called inversion, but reversion. Various points connected with reversion (to keep the common term) will be met with in TAYLOR'S THEOREM and SERIES; the present article is meant purely for reference upon the most usual case of the problem, which is not sufficiently developed in elementary works; that is, enough of the result for reference is not put down.

The problem is as follows:—Given $y = ax + bx^2 + cx^3 + ex^4 + fx^5 + \ldots$; required x in a series of the form $\text{A}y - \text{B}y^2 + \text{C}y^3 - \text{E}y^4 + \ldots$. It will be proper first to put down the coefficients in connection with the exponents to which they belong, as follows:—

1	2	3	4	5	6	7	8	9	10	11
a	b	c	e	f	g	h	k	l	m	n
A	B	C	E	F	G	H	K	L	M	N

It will be convenient, instead of writing the resulting series $\text{A}y - \text{B}y^2 + \ldots\ldots$, to let it be $\text{A}a^{-1}y - \text{B}a^{-3}y^2 + \text{C}a^{-5}y^3 - \text{E}a^{-7}y^4 + \text{F}a^{-9}y^5 - \text{G}a^{-11}y^6 + \text{H}a^{-13}y^7 - \text{K}a^{-15}y^8 + \text{L}a^{-17}y^9 - \text{M}a^{-19}y^{10} + \text{N}a^{-21}y^{11} - \ldots\ldots$ We then have

$\text{A} = 1$

$\text{B} = b$

$\text{C} = 2b^2 - ac$

$\text{E} = 5b^3 - 5abc + a^2e$

$\text{F} = 14b^4 - 21ab^2c + 3a^2(2be + c^2) - a^3f$

$\text{G} = 42b^5 - 84ab^3c + 28a^2(b^2e + bc^2) - 7a^3(bf + ce) + a^4g$

$\text{H} = 132b^6 - 330ab^4c + 60a^2(2b^3e + 3b^2c^2) - 12a^3(3b^2f + 6bce + c^3) + 4a^4(2bg + 2cf + e^2) - a^5h$

$\text{K} = 429b^7 - 1287ab^5c + 495a^2(b^4e + 2b^3c^2) - 165a^3(b^3f + 3b^2ce + bc^3) + 45a^4(b^2g + 2bcf + be^2 + c^2e) - 9a^5(bh + cg + ef) + a^6k$

$\text{L} = 1430b^8 - 5005ab^6c + 1001a^2(2b^5e + 5b^4c^2) - 715a^3(b^4f + 4b^3ce + 2b^2c^3) + 55a^4(4b^3g + 12b^2cf + 6b^2e^2 + 12bc^2e + c^4) - 55a^5(b^2h + 2bcg + 2bef + c^2f + ce^2) + 5a^6(2bk + 2ch + 2eg + f^2) - a^7l$

$\text{M} = 4862b^9 - 19448ab^7c + 8008a^2(b^6e + 3b^5c^2) - 1001a^3(3b^5f + 15b^4ce + 10b^3c^3) + 1001a^4(b^4g + 4b^3cf + 2b^3e^2 + 6b^2c^2e + bc^4) - 286a^5(b^3h + 3b^2cg + 3b^2ef + 3bc^2f + 3bce^2 + c^3e) + 22a^6(3b^2k + 6bch + 6beg + 3c^2g + 3bf^2 + 6cef + e^3) - 11a^7(bl + ck + eh + fg) + a^8m$

$\text{N} = 16796b^{10} - 75582ab^8c + 15912a^2(2b^7e + 7b^6c^2) - 12376a^3(b^6f + 6b^5ce + 5b^4c^3) + 2184a^4(2b^5g + 10b^4cf + 5b^4e^2 + 20b^3c^2e + 5b^2c^4) - 273a^5(5b^4h + 20b^3cg + 20b^3ef + 30b^2c^2f + 30b^2ce^2 + 20bc^3e + c^5) + 182a^6(2b^3k + 6b^2ch + 6b^2eg + 6bc^2g + 3b^2f^2 + 12bcef + 2c^3f + 2be^3 + 3c^2e^2) - 78a^7(b^2l + 2bck + 2beh + c^2h + 2bfg + 2ceg + cf^2 + e^2f) + 6a^8(2bm + 2cl + 2ek + 2fh + g^2) - a^9n.$

We have given these coefficients to an extent which many will think useless, and in fact it will not often be necessary to employ all that are here given. But we have two objects in view: first, to enable those who want these coefficients to refer to them; secondly, to point out the great advantage of some methods which are never given in elementary works, and are not so much known and practised as methods of such utility and power should be.

The usual way of obtaining these results is to take the series $x = \text{A}a^{-1}y - \text{B}a^{-3}y^2 + \ldots\ldots$, and in it to substitute the value of y, namely, $ax + bx^2 + \ldots$. This would give

$$x = \frac{\text{A}}{a}(ax + bx^2 + \ldots) - \frac{\text{B}}{a^3}(ax + bx^2 \ldots)^2 + \ldots,$$

the two sides of which equation must be identical; giving

$$\text{A} = 1,\ \text{A}\frac{b}{a} - \text{B}\frac{1}{a} = 0, \text{ or B} = b;$$

$$\frac{\text{A}}{a}c - \frac{2b}{a^2}b + \frac{\text{C}}{a^2} = 0, \text{ or C} = 2b^2 - ac,$$

and so on; but this process would become intolerably tedious and liable to error after a few steps: that which we have followed in forming the preceding coefficients [TAYLOR'S THEOREM] would have enabled us with comparatively little difficulty and small risk of error to double their number. It also gives the law of the coefficients, which is as follows:—

1. What sort of terms enter into M, the coefficient of y^{10}? Write down every way in which 2 . 10 − 2, or 18, can be made up of 10 − 1, or 9, numbers, and, taking the letters belonging to these numbers from the table, we have the literal parts of the different terms of the coefficients. Thus

18 is made up of the nine numbers, 1, 1, 1, 1, 2, 2, 2, 2, 6, the letters of which are $a, a, a, a, b, b, b, b, g$: accordingly, a^4b^4g is the literal part of one of the terms of M. And similarly for every other combination of nine numbers which make 18.

2. What is the coefficient of any given term? Say that y^n is the power to which the term belongs, and that $a^\alpha b^\beta c^\gamma \ldots$ is the literal part of it. The coefficient required is as follows:

$$\frac{(n+1)(n+2)\ldots\ldots(2n-\alpha-2)}{(1.2.3\ldots.\beta)(1.2.3\ldots.\gamma)(1.2.3\ldots.\delta)\ldots.}$$

Thus, to verify the numerical coefficient of $a^6c^2e^2$ in N, the coefficient of y^{11}, we must calculate ($n = 11$, $\alpha = 6$, $2n - \alpha - 2 = 14$),

$$\frac{12\,.\,13\,.\,14}{(1\,.\,2)\,(1\,.\,2)}, \text{ which is } 6\,.\,13\,.\,7, \text{ or } 546,$$

and 182 × 3, the coefficient in the table, is also 546.

2. The sign of any term is positive or negative according as the power of a which it contains is even or odd.

We may thus verify any one term, and the coefficients may be sufficiently verified, as to typographical correctness, by remembering, that if $a = b = c = \&c. = 1$, we should have $\text{A} = \text{B} = \text{C} = \&c. = 1$; for $y = x + x^2 + x^3 + \ldots$ gives $x = y - y^2 + y^3 - \ldots.$ The result of the use of the preceding table, distinguishing the positive from the negative parts, is

$$x = y - y^2 + (2-1)y^3 - (6-5)y^4 + (23-22)y^5 - (99-98)y^6 + (452-451)y^7 - (2140-2139)y^8 + (10397-10396)y^9 - (51525-51524)y^{10} + (259430-259429)y^{11}.$$

The preceding is a particular case of the following general problem, which frequently occurs, and is very complicated in its details. Given $y_m = ax^m + bx^{m+1} + cx^{m+2} + ex^{m+3} + fx^{m+4} + \ldots$; required a series for x in powers of y. Let it be assumed that

$$x = \text{A}\frac{y}{a^n} - \text{B}\frac{y^2}{a^{2n+1}} + \text{C}\frac{y^3}{a^{3n+2}} - \text{E}\frac{y^4}{a^{4n+3}} + \text{F}\frac{y^5}{a^{5n+4}} - \ldots\ldots$$

n being $1 . m$. Then $\text{A} = 1$, $\text{B} = nb$:

$$\text{C} = n\frac{3n+1}{2}b^2 - n\,ac$$

$$\text{E} = n\frac{4n+1}{2}\,\frac{4n+2}{3}b^3 - n\frac{4n+1}{2}2abc + n\,a^2e$$

$$\text{F} = n\frac{5n+1}{2}\,\frac{5n+2}{3}\,\frac{5n+3}{4}b^4 - n\frac{5n+1}{2}\,\frac{5n+2}{3}3ab^2c$$

$$+ n\frac{5n+1}{2}a^2(2be + c^2) - n\,a^3f$$

Methods of obtaining all these series are given in TAYLOR'S THEOREM.

REVERSION. "Reversion of land is a certain estate remaining in the lessor or donor, after the particular estate and possession conveyed to another by lease for life, for years, or gift in tail. And it is called a reversion in respect of the possession separated from it; so that he that hath the one, hath not the other at the same time, for being in one body together, there cannot be said a reversion, because by the uniting, the one of them is drowned in the other. And so the reversion of land is the land itself when it falleth." ('Termes de la Ley.') Thus if a man seised in fee simple conveys lands to A for life, or in tail, he retains the reversion in fee simple. The distinction between a remainder and a reversion has been explained in REMAINDER. In all cases where the owner of land or the person who has an estate in land, grants part only of his estate, he has a reversion; and as the grantee holds of him, there is tenure between them, and the grantor has a seignory by virtue of having a reversion. When a man grants all his estate to another, or grants a particular estate to A, and various remainders over, remainder to F in fee, he has no reversion left, and therefore he has no seignory since the passing of the statute of Quia Emptores. The remainder-men also who precede the remainder-man in fee, do not hold of such remainder-man, but of the lord of the fee of whom the original owner held. The word reversion is often used inaccurately, and it is sometimes necessary to recur to its strict legal signification.

Before the passing of the statute De Donis, if a man seised in fee simple granted his lands to a man and the heirs of his body, he had no reversion, for the grantee was considered to have a conditional fee. But since this statute, an estate to a man and the heirs of his body has always been considered to be a particular estate.

If a man grants a lease of lands in possession, at common law, he has no reversion until the lessee enters by virtue of his lease, for the lessee has no estate until he enters; but if the term of years is created under the Statute of Uses, as by bargain and sale, the lessee has a vested estate by virtue of the statute, without entering on the land, and consequently the lessor has a reversion. It is said that a reversion cannot be created by deed or other assurance, but arises from construction of law. This means that a reversion is not created by the act of the party who conveys part of his estate, but is a legal consequence of his acts. If a man seised in fee simple limits his estate to another for life or in tail, remainder to himself in fee or to his own right heirs, he has not a remainder, but a reversion. Yet by 3 and 4 Wm. IV. c. 106, the effect of such a limitation is to vest such a remainder in fee in the settlor by *purchase*, and he is not to be considered to be entitled to it as his former estate or part thereof.

A reversion is a vested estate, which may be granted or conveyed, and charged like an estate in possession; and in some cases the reversioner in fee may bring an action, as well as the tenant in possession, for an injury to his inheritance.

Fealty is an inseparable incident to a reversion. There may or may not be a rent reserved, but fealty is always due from the owner of the particular estate to the reversioner, and it cannot be separated from the reversion, though the rent, if there be one reserved, may be separated from it. [Rent.] Reversions which are expectant on estates for years are subject to dower and courtesy; but this is not the case with reversions expectant on a freehold estate.

When a reversion expectant on an estate tail comes into possession, it is liable to the leases made by those who were at any time entitled to the reversion, and to the covenants contained in such leases. All particular estates, except an estate tail, are subject to merge in the reversion, when the particular estate and the reversion are united in the same person. Formerly when an estate tail was converted into a base fee, and the remainder or reversion in fee in the same lands became united in the same person, the base fee was subject to merger in the reversion; but by the 3 and 4 Wm. IV. c. 74, when such union takes place, "the base fee shall not merge, but shall be *ipso facto* enlarged into as large an estate as the tenant in tail, with the consent of the protector, if any, might have created by any disposition under this Act, if such remainder or reversion had been vested in any other person." Before this statute, when a base fee thus merged in the reversion, the reversion became an estate in possession, and liable to all the leases and charges of those who had at any time been entitled to it.

REVETMENT, in permanent fortification, is a wall of brick or stone retaining the mass of earth which constitutes the rampart, generally on the exterior side only, or retaining the earth which forms the opposite side of the ditch. The exterior faces of these walls are considered as the scarp and counterscarp of the ditch.

In and before the time of Vauban the scarp revetments were raised from the bottom of the ditch to the top of the parapet; but the part which was visible above the glacis being destroyed by the enemy's artillery, and the parapet in consequence partly ruined soon after the commencement of the siege, that engineer in most of his works raised his revetments no higher than the level of the crest of the glacis, or about 7 feet above the natural ground; the exterior of the parapet was then left at such an inclination to the horizon (45° in general) that the earth would support itself. The ditch of a fortress being about 18 feet deep, the height of the scarp revetment was consequently 25 feet, and this was considered sufficient to afford security against the danger of having the rampart escaladed. At present it is recommended that the main ditch should be 24 feet deep, and in this case the scarp revetment is above 30 feet high. In constructing the fortifications of Neuf Brisac, Vauban made the revetments of the scarps both of the enceinte and of the reduit of the ravelin, as high as the top of the parapet; but these works being covered by the counterguard or the ravelin, their revetments would be unseen by the enemy at a distance, and therefore not liable to the objection above mentioned.

The form usually given in profile to revetments of masonry may be seen at M and N, *Fig.* 2, Bastion; the first is the revetment of the counterscarp, and the other that of the scarp. The rectangular parts are sections through the counterforts or buttresses which are built up with the walls in order to strengthen them, at intervals of about 15 feet from each other. Scarp revetments, whose tops are as high or higher than the crest of the glacis, are called full revetments; while such as are no higher than the level of the natural ground are called demi-revetments.

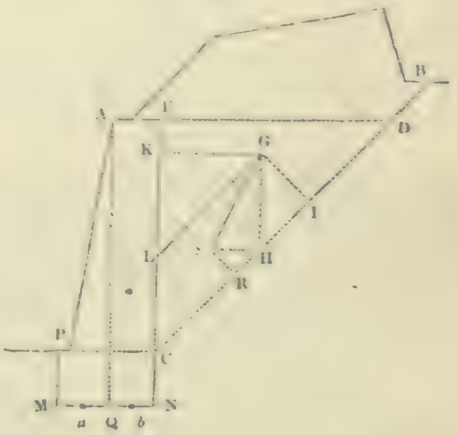
In order that the revetment might most effectually resist the pressure of the earth which it is to support, Vauban gave to the exterior face of the wall a slope, whose horizontal breadth was equal to one fifth of the height; this was subsequently reduced to one sixth, and now it is thought to be most advantageous to make the face vertical. By giving the slope to the rear face of the wall, that is, by making the revetment countersloping, all the advantages of a slope are gained, while the disadvantage of rapid vegetation on the face is avoided.

In laying the foundations of revetments in defective soils, the same methods are used as in the construction of civil edifices; and in all cases the courses of stones or bricks are laid obliquely to the horizon, inclining down towards the part under the earth which is to be supported, in order that the pressure of the latter may be more directly resisted. But as the bed joints of brickwork when so disposed allow the rain to penetrate, and the seeds of grass to lodge in them, it is thought that the wall is more speedily degraded when so built than when the courses are laid horizontally; therefore in order to unite the advantages of direct resistance and durability, it is customary to place the courses obliquely, but to lay one row of bricks in each course at the face of the wall in a horizontal position.

The exterior and interior faces of the revetment, or retaining wall of a dock, have in a vertical section the form of concentric arcs of circles, with their convexities towards the land; and this form is given them that the stones may be able to resist the hydrostatical pressure of any water which, when the dock is full, may get behind the wall, and which may be prevented from escaping when the dock is made dry.

Some of the ramparts of Coehorn and all of those which Carnot proposed for his fortresses, are formed of earth unsupported by revetments; and even the opposite side of the ditch, instead of being faced with a steep wall, is by the latter engineer cut with a gentle slope from the level of the natural ground to the bottom of the ditch. But the fortifications of Coehorn are provided with wet ditches, which prevent the besiegers from getting to the foot of the rampart by surprise: and in those of Carnot a high detached wall covered by a counterguard of earth puts it out of the power of the enemy, while that wall stands, to get across the ditch. Without such obstacles the unreveted rampart would afford great facilities to the enemy in an effort to carry the fortress by assault. Its exterior slope must form at most an angle of 45° with the horizon, that the earth may support itself, and consequently it may be easily ascended; and any palisades or other impediments which the defenders might place on it would soon be displaced or destroyed by the batteries of the enemy. Besides these evils, the exterior slope, from its breadth, occupies a great portion of ground; it consequently obliges the engineer to contract the space enclosed within the works, and thus to sacrifice in some measure the convenience both of the inhabitants and the garrison.

In order to investigate the conditions of stability in revetment walls, let E B C be a vertical section through the mass of earth retained by the wall; B C being the slope which earth is supposed to assume when unsupported, and let A E M N be a section of the wall, E C being the level of the bottom of the ditch, and M N being the bottom of the foundation. Imagine G to be the centre of gravity of the section E C B; draw G L parallel to B C and G K parallel to the horizon: then, by the resolution of forces, K L and G K will have to one another the same proportion that the weight of the unsupported prism of earth (of any thickness) bears to its horizontal pressure. Let W be that weight; then $\frac{\text{K G}}{\text{K L}}$ will express that pressure, and $\frac{\text{K G}}{\text{K L}}.\text{W}.\text{K N}$ will be the momentum or power by which the earth tends to overturn the wall about M.



Imagine the vertical line A Q to be drawn: then the form and dimensions of the part A M Q of the wall are known; and let it be required to find the breadth Q N of the rectangular part A N, so that the resistance of the whole shall be equal to the momentum of the supported earth. Suppose the centre of gravity of A M Q to be found, and let it be vertically over a. The centre of gravity of the rectangular part is vertically over b, the middle of Q N; and let Qb be represented by x. Then if g be the specific gravity of the wall, we have by mechanics, $\text{AMQ}\,.\,\text{M}a\,.\,g+\text{AQ}\,.\,\text{M}b\,.\,g\,.\,x$ for the resistance of the wall; consequently equating this expression with the above momentum of the earth, the value of x, and therefore of Q N, can be found. But great uncertainty exists respecting the position of the line of rupture B C, from our ignorance of the allowance to be made for the effect of friction on the tendency of the earth to slide downwards. Experiments have led to the opinion that this effect is equal to half the pressure of the earth perpendicularly upon the inclined plane which it would assume if unsupported; and that value is frequently adopted. Coulomb showed that the angle which the line of rupture makes with the vertical is half the angle which the line of natural slope makes with the vertical.

In order to find the magnitude which the triangle E D C should have when the supported earth exerts the greatest pressure against the wall, the following process may be used; the earth above A D being at present, for simplicity, supposed to be removed. Imagine G to be the centre of gravity of that triangle, and the vertical line G H to be drawn; then G H may represent the weight of the unsupported earth, and let it be resolved into the pressures represented by G I and I H, the former perpendicular to the slope, and the latter coincident with it. Imagine H S to be drawn to represent the reaction of the wall A M N, and let it be resolved into the forces represented by S R and R H, perpendicular to and coincident with the slope, respectively. Then, I H representing the force with which the prism of earth would tend, if without friction, to slide down D C, R H represents the reaction by which the wall resists that force; while G I and S R represent the pressure and reaction perpendicular to D C. Consequently, the friction being supposed to be equal to half the pressure, we have $\frac{1}{2}(\text{G I}+\text{S R})$ for the effect of friction; and in the case of equilibrium, $\text{I H}=\text{R H}+\frac{1}{2}(\text{G I}+\text{S R})$.

Let $\text{E C}=h$, $\text{E D}=z$, $\text{H S}=p$, and let g be the specific gravity of the earth; then $\frac{hgz}{2}$ expresses the weight of the prism whose section is E D C, and whose thickness is unity, and which was represented by G H; and the triangles G I H, H S R being similar to E C D, we get by proportions $\text{I H}=\frac{h^2gz}{2\,\text{C D}}$, $\text{H R}=\frac{pz}{\text{C D}}$, $\text{G I}=\frac{hgz^2}{2\,\text{C D}}$, and $\text{S R}=\frac{ph}{\text{C D}}$. These values being substituted in the above equation, the value of the pressure H S or p will be found to be $\frac{h}{2}g \cdot \frac{2hz-z^2}{2z+h}$. Now this quantity is to be a maximum; therefore making its differential relatively to z equal to zero, the value of z will be found to be $\cdot 618h$; whence $p=\cdot 1908\,g\,.\,h^2$. If this equation be differentiated relatively to h, the result will express the horizontal pressure against an elementary portion of the wall at a variable height (which represent by h) above C: therefore multiplying by h and integrating, we get $\cdot 1272\,g\,h^3$ for the whole force exerted by the earth to overturn about M a wall whose height E C is represented by h, when that force is a maximum. When there is a parapet above A D, its weight, expressed by the product of the area of the section multiplied by g, must be added to the above expression for the weight of the prism E D C in the preceding investigation, in order to obtain the value of the expression which is represented by G H.

Instead of making a revetment in the form of a simple wall, it is customary to build buttresses or counterforts at intervals from each other on the side next to the supported earth; consequently the thickness of the wall itself may be rather less than that which would result from the above equation. In order to determine it, if we assume, for example, that the distance from the centre of one counterfort to that of the next is fifteen feet, the area of a horizontal section fifteen feet long and taken at the mean height of the wall, if the face has a slope, together with the area of the like section through the two half counterforts, may be equal to the area of a section of the simple wall (of the same length) as determined by the above investigation; then deducting one-fifth of that quantity for the two half counterforts, the remainder divided by 15 will give the required breadth of a horizontal section at the part between the counterforts. It should be observed, however, that the thickness of a brick revetment which is to resist the fire of a battering train should not be less than seven or eight feet. It is usual to make the depth of a counterfort equal to the mean breadth of the wall; and to give it greater thickness at the part which joins the wall than at the other extremity.

Counterforts serve in part as props to keep the wall from inclining in consequence of partial compressions in the cement; but chiefly by extending the breadth of the base at intervals they increase, at the places where they are formed, the length of the arm of the lever by which the weight of the wall resists the lateral pressure of the earth. The usual connection of the bricks or stones in the wall with those of the counterforts allows this advantage to be extended in nearly an equal degree to the parts which are situated between the counterforts. But in order that the connection may be more complete, it has been recommended to connect the tails of every two counterforts by a wall curved on the plan, and having the convex side towards the earth which is to be retained. Again, the nearest sides of every two counterforts have occasionally been connected by two or more arches, one above another; by which means the mass of retained earth is in part supported, and the lateral pressure of the whole is diminished.

Revetments in which the counterforts are connected in either of these ways are said to be counter-arched; and it is recommended that arches of the latter kind should be formed in the mass of the parapet above the cordon of the scarp. It is also recommended that the masonry of the arches in the rampart should be but slightly connected with that of the revetment wall; since the greater part of the rampart and parapet will then remain supported by the arches even after the revetment has been demolished by the artillery of the besiegers. When the scarp revetment is carried completely up to the superior slope of the parapet, leaving no exterior slope, it is termed a *full revetment*. When there is an exterior slope left it is termed a *demi-revetment*.

REVIVOR. [SCIRE FACIAS.]

REVOLUTION. This well-known term is applied in astronomy to the manner in which a detached body moves round another, as a planet round the sun; but the motion of connected particles of matter round an axis, such as the diurnal revolution of a planet, is more usually called ROTATION.

In pure mathematics the word revolution is applied to the angle moved over by a line which revolves round a point from any one position to that position again; it is therefore a synonyme for four right angles.

REVOLVERS are fire-arms in which the barrels, or a portion of the barrels, being made to turn round on the cocking of the piece, are brought successively under the hammer, and permit of a rapid succession of discharges from the same piece. Revolvers, or repeating fire-arms, are not an invention of modern times; many of a very ancient date are to be seen in museums and collections of old arms. These are in several points very similar to the most recent improvements, but it was not till the introduction of the percussion cap removed the difficulty of retaining the priming of each charge in its place during the rotation of the chamber, that the revolver could be considered a really serviceable weapon; while at the same time it was not till the great improvement of modern times in cheap accurate machine manufacture that it became practicable to make such instruments in large numbers. For many years revolvers were made with the barrels all in one: five or six barrels being fixed together were made to revolve round a central axis, so as to bring their nipples successively under the hammer.

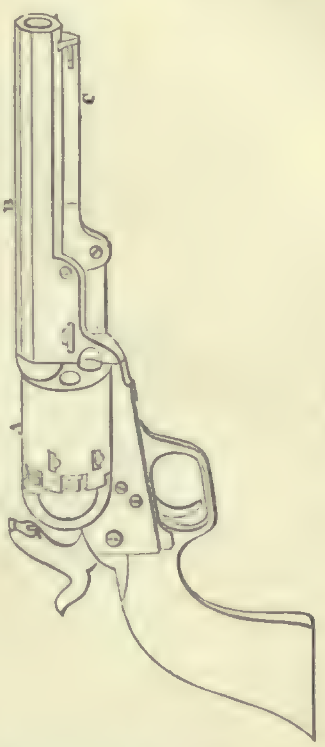


Fig. 1.—A, the chamber; B, the barrel, rifled; C, the lever-ramrod.

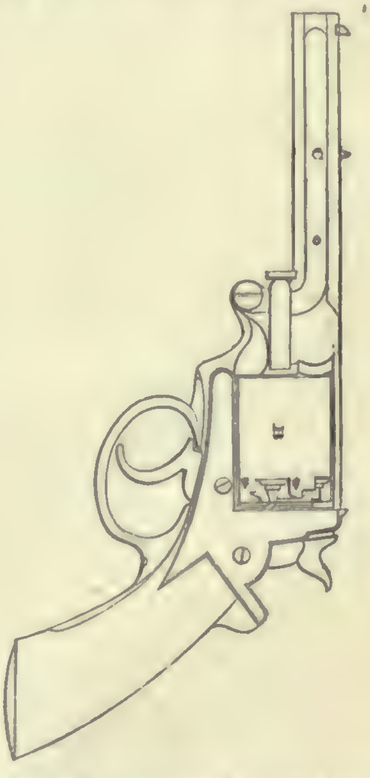


Fig. 2.—A, the barrel; B, cylinder or chamber; C, lever-ramrod.

This, however, even when the bullet was almost unserviceably small, was a heavy clumsy weapon. The adoption of revolving chambers and one barrel overcame this difficulty. *Fig.* 1 shows the outline of Colonel Colt's revolver. This pistol first became generally known in England at the Great Exhibition of 1851, where it excited a good deal of attention. It had been for some years much used in America, and found of great service in bush-fighting and in the backwoods. This undoubtedly set English gunmakers to work in the same direction, for numerous revolving pistols have since been invented in England. There are three sizes of Colt's pistol, the smaller containing five chambers. The bullets may be either spherical or conical, and are made slightly larger than the chamber, into which they are forced by the lever rammer, and fit so tightly that the pistol can be carried in the holster, muzzle downwards, without their being shaken from their places. The chamber is again slightly larger than the barrel, which, being rifled, the bullets on being forced through them take the rifling most effectively.

Fig. 2 represents Adams's revolver, which, since its invention, has received numerous improvements (especially the lever-ramrod, which the earlier pistols were not provided with), and may now be considered the most efficient arm of this description. In Colt's pistol it is necessary to cock the piece with the thumb before each discharge, while Adams's pistol can be fired with only a continuous pull of the trigger; this gives the latter a great advantage in rapidity, an important point with a pistol which is not so much required for long accurate shots as for quick shooting in a mêlée. By another improvement in Adams's pistol, however, we are enabled to cock it for accurate shooting with the trigger or the thumb, when a further slight pull fires the pistol. *Fig.* 3, lock of Adams's revolver, and *fig.* 4, of Colt's revolver, which are taken from 'Straith's Artillery,' by Cook and Hyde, will explain the action of the locks in the two pistols. Revolving or repeating pistols will undoubtedly supersede all others, as being far the most efficient arm; good shooting may be made with them at 100 or 200, and fair even at 300 yards. For cavalry, on board ship, or at close quarters generally, they are a most formidable weapon. Rifles and large firearms have been made on the same principle, and for some purposes they may be very useful; but they labour under the disadvantage of reduced penetrative power and range from the escape of gas at the junction of the chamber and barrel, which has never yet been completely overcome.

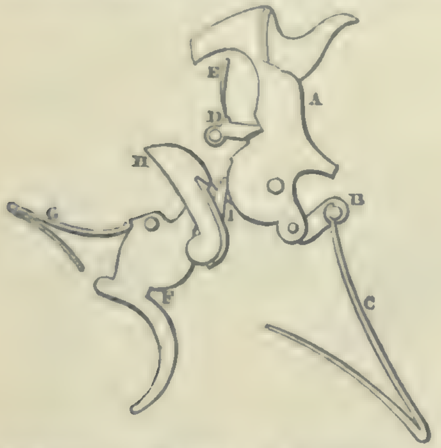


Fig. 3.—A, is the hammer; B, the swivel; C, the main-spring; D, the short sear; E, the short sear spring; F, the trigger; G, the trigger spring; H, the lifter and spring; I, the long sear.—The position of the action is that in which the hammer is down on the nipple.

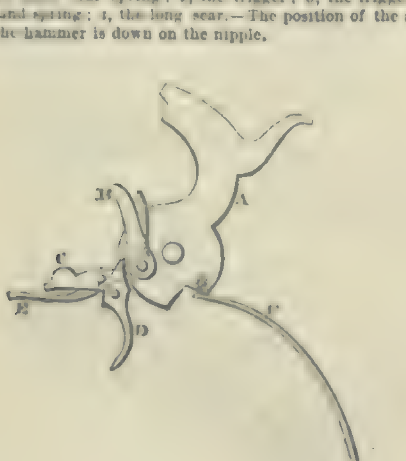


Fig. 4.—A, is the hammer; B, the hand or lifter, which gives motion to the chamber; C, the bolt, which secures the chamber while the hammer falls; D, the trigger; E, the sear and trigger spring; F, the main-spring.

RHAMNIN. A yellow crystalline substance obtained from the buckthorn (*Rhamnus catharticus*), and apparently identical with *chrysorhamnin*.

RHAMNOXANTHIN. A yellow crystalline body found in the seeds and bark of the *Rhamnus frangula*, and of the *Rhamnus catharticus*. It is volatile, slightly soluble in water, and very soluble in alcohol and ether.

RHAPONTICIN. Synonymous with CHRYSOPHANIC ACID.

RHAPSODY (ῥαψῳδία) was a poem sung by a rhapsodist, generally applied to detached parts of the Homeric poems, the Iliad and the Odyssey. But the word rhapsodist properly signifies one who sews or fastens things together; and it was specially applied to those who arranged or are supposed to have arranged the parts of the Homeric poems and of other old poems, so as to make one entire work of them, and who went about from place to place to sing and recite those poems. In modern use the word has an entirely different signification. A rhapsody is a discourse or writing in which the parts have no necessary dependence on each other.

RHEA, one of the divinities of ancient Greece and Rome. Rhea was the daughter of Uranus and Gæa, and the sister and wife of Kronos, by whom she had several children who were successively swallowed by Kronos, till she succeeded in imposing on him a stone for the new-born Zeus. [KRONOS; ZEUS.] Rhea became early identified with the Phrygian mother-goddess Cybele; and also by some of the Greek races, with her daughter DEMETER. Besides the names Rhea, Cybele, &c., she was called "the mother of the gods," "the great mother," &c. The original seat of her worship appears to have been Crete, but it soon spread through Greece. As the great goddess of the eastern nations, her worship was however far more widely extended. The rites of Rhea were in some places mingled with those of Dionysos; and her priests, the Corybantes, leapt, danced, sung, and performed various frenzied orgies in the wilds of Phrygia. As the mother of Jupiter, under the name of Ops, she was worshipped by the Romans from the earliest times. Her festival at Rome was called the Megalesia; her priests were eunuchs, and named Galli. The oak and the lion were sacred to her. In Greek art Rhea is represented wearing a crown with towers, and she carries in her hand a key or a branch. She is usually seated on a throne with lions beside her; or in a car drawn by lions; sometimes she is riding on a lion; in bassi-relievi, &c., she is sometimes seen attended by dancing Corybantes with cymbals.

RHEADIC ACID. [PAPAVERIC ACID.]

RHEIC ACID. [CHRYSOPHANIC ACID.]

RHEIN. [CHRYSOPHANIC ACID.]

RHEOMETER. A number of instruments, &c., used in GALVANISM are named by French physicists *rheometer*, *rheophose*, *rheotrope*, *rheostat*, from the Greek ῥέω, to flow. The words have only been to a limited extent adopted in this country. [GALVANOMETER.]

RHETORIC (ῥητορική) is a Greek word of similar import to the Latin oratory; but a rhetorician is a teacher of or writer on oratory, and an orator is one who practises the art; Demosthenes was an orator, Aristotle was a rhetorician, and Cicero was both.

English writers, in treating of rhetoric, appear generally to consider it the same as oratory, and perhaps it is difficult to make a distinction between them. Cicero's 'Orator,' 'De Oratore,' and 'De Claris Oratoribus,' are always called rhetorical works. Quinctilian ('Inst.,' ii. 14) speaks of persons who translated the Greek word "rhetorice" into Latin by "oratoria" and "oratrix;" but he objects to the use of both these words, and adopts the Greek word, which, he says, Cicero himself employed to designate certain books (probably the two books 'De Inventione') which he had written on this art. An account of Quinctilian's work on the same subject will be found under QUINCTILIANUS, in BIOG. DIV. In the article ORATORY it is stated that the treatise of Aristotle on rhetoric is the oldest extant treatise on this art, and one of the most valuable books preserved from ancient times. The present article seems to furnish a suitable occasion for giving a short account of Aristotle's work.

Aristotle begins by saying that rhetoric is the counterpart (ἀντίστροφος) of logic, and he defines it to be the faculty (δύναμις) of perceiving on any given subject what is best adapted to persuade. He divides rhetoric into three parts: Persuasion (πίστις, or rather πίστεις), Language or Expression (λέξις), and Arrangement (τάξις). His work consists of three books, of which the first and second treat of persuasion, and the third treats of expression and arrangement.

After premising some general remarks on rhetoric, he treats of persuasion as derived from enthymemes (ἐνθυμήματα). Having stated that there are three kinds of persuasion, the deliberative (συμβουλευτικόν), the demonstrative (ἐπιδεικτικόν), and the judicial (δικανικόν), and that, in reference to each of these, persuasion is both special (ἴδιαι) and general (κοιναί), c. 3, he discusses the subject of special persuasion in each kind: touching the deliberative he inquires whether it be useful, c. 4 to 8; touching the demonstrative, whether it be honourable, c. 9; touching the judicial, whether it be just, c. 10 to 15. He concludes the first book by stating and explaining the modes of producing persuasion without the art of rhetoric, c. 16.

In the second book he proceeds to say that, in reference to certain questions, special persuasion must be considered as depending on the character of the speaker, c. 1; and on the passions of the hearers, c. 2 to 13; as also on the general character of the hearers, such as their passions, their moral habits, their different ages and conditions in life, c. 17 to 19. He closes the discussion of special persuasion by viewing it in connection with questions common to the three kinds of persuasion, such as possibility, fact, futurity, and magnitude, c. 19. He then proceeds to persuasion considered generally and indefinitely, of which he mentions two kinds, example (παράδειγμα) and enthymeme (ἐνθύμημα), adding *γνῶμαι* (γνώμη) as included in enthymeme, c. 20 to 26.

He commences the third book with the second part of rhetoric, namely, expression. He states what is necessary to constitute expression, c. 2 to 4; and describes its various forms, c. 5 to 9. He treats of elegance (τὰ ἀστεῖα), c. 10, 11; and represents the different kinds of expression, c. 12.

He then comes to the third part of rhetoric, which is arrangement. This, he says, consists necessarily of two parts, the proposition of any subject, and its confirmation; but there may be four parts, introduction (προοίμιον), proposition (πρόθεσις), confirmation (πίστις), and peroration (ἐπίλογος). He concludes the work by discussing these four parts of arrangement: introduction, c. 14, 15; proposition, c. 16; confirmation, c. 17; peroration, c. 19.

Aristotle's 'Rhetoric' is not only the best treatise upon this subject, but a model of profound thinking and reasoning for the investigation of various other subjects.

RHEUM (*Rhubarb*), *Medical Properties of.* As the particular species which yields the officinal rhubarb, and even the precise place of its growth, are not known, the varieties met with in commerce are here described, without attempting to assign them to any ascertained species. There are six well-marked varieties, namely, Russian or Turkey, Dutch-trimmed, Chinese, Himalayan, English, and French. Of the first sort the greater portion at present comes from St. Petersburg, and is denominated Muscovite, Bokharian, or Siberian rhubarb, while a "part has always formed one of the imports from China into Bokhara, whence passing to Smyrna, it is known in Europe as Turkey rhubarb" (Royle, 'Flora of the Himalaya'), which name it commonly bears in the shops. This kind varies much in size and appearance, the pieces being cylindrical, spherical, flat, or irregular, from two to three inches long, one to three broad, and one to three thick. "The smaller pieces are picked out, being preferred, while the larger pieces and the dust are employed for powdering." Holes are remarked in many of the pieces, of which one occasionally extends entirely through, the others only partially; the former having been made in order to suspend the piece in drying, the others in examining the quality. This kind, and probably the other sorts, is frequently worm-eaten, owing to the ravages of a small beetle, *Sinodendrum pusillum.* (Kirby and Spence, 'Entomology,' i. p. 252.)

Externally the pieces are covered with a bright yellow-coloured powder, which either results from the friction of the pieces during their passage to this country, or from the process of rouncing (that is, shaking in a bag with powdered rhubarb), previous to its exportation. The odour is strong, both of the root and fresh powder, peculiar, somewhat but not pleasantly aromatic. When chewed, it feels gritty, owing to the presence of numerous raphides (or crystals of oxalate of lime, which are present to the amount of between 30 and 40 per cent.); it communicates a bright yellow colour to the saliva, and has a bitter, slightly astringent taste, which to some persons is not unpleasant, as they are in the habit of chewing rhubarb to obtain its tonic effects on the stomach; but this practice is objectionable from the yellow colour it imparts to the teeth and gums.

When the dust which covers the surface is removed, it exhibits a more or less reddish-yellow hue with white lines interspersed, which form beautiful reticulations, best seen on a vertical section, while a transverse section exhibits small star-like spots and depressions of a darker colour. The transverse fracture is uneven, the longitudinal still more so. "The powder of genuine Russian rhubarb is of a bright yellow colour, verging to red, but as met with in the shops it is almost invariably mixed with the powder of English rhubarb," which gives it a much lighter colour.

The analysis of this sort by Hornemann shows it to consist of—

Rhubarberin (or bitter principle of Pfaff)	16
Yellow colouring matter (of Henry)	9
Bitter extractive	14
Oxidized tannin	1
Mucilage	10
A substance extracted from the woody fibre	28
Oxalic acid	1
Woody fibre	14
Moisture, loss, odorous principle	3

Rhubarberin is also called chrysophanic acid, or yellow crystalline granulated matter of rhubarb. According to Schlossberger and Doepping, rhubarb contains three resins: Aporetine, Phaeoretine, and Erythoretine. It is supposed to contain some volatile oil, to which the peculiar odour is due.

The chief chemical distinction between this and English rhubarb is the presence in the latter of a principle termed *rhaponticin*, and 14 per cent. of starch, with a smaller portion of rhubarberin, of yellow colouring matter and extractive: iodine furnishes a ready distinguishing test, for a "decoction of Russian, Dutch-trimmed, or Chinese rhubarb becomes, with a solution of iodine, greenish-blue (iodide of starch); after a few minutes the colour disappears, and no iodine can be detected in the liquor by starch, unless nitric acid be previously added; a decoction of English rhubarb is rendered by a solution of iodine intensely blue (iodide of starch), the colour not completely disappearing by standing." (Pereira.) This difference is clearly dependent on the much greater portion of starch existing in English rhubarb. Inferior rhubarb, or roots cut to resemble rhubarb, and sprinkled over with powdered turmeric, or dyed with it, may be detected by means of boracic acid, or any borates rendered acid, since the colour of genuine rhubarb, or paper dyed with it, is not affected by these re-agents, whereas turmeric-paper is reddened by them. Yellow ochre, with which black and worthless pieces are covered, or which is used to fill the holes in worm-eaten pieces, may be detected by heat, as it burns with a brownish red appearance, and exhibits the characters of a ferruginous earth.

Portions unusually white are occasionally found in the chests of Russian rhubarb, and are presumed to be specimens of *imperial rhubarb;* nothing certain is known of its origin or relative value, but it is assigned to *Rheum leucorrhizum*, Pallas, *R. nanum*, Sievers, *Rheum tataricum*, Linn.

2. Dutch-trimmed rhubarb, called also by some writers Persian rhubarb, and Batavian, occurs in flat or round pieces, and is not much different in appearance from the preceding, but it reaches Europe through Canton and Singapore. It is said to be very liable to the attacks of a small coleopterous insect, *Anobium boleti*, and that the holes so made are stopped with yellow ochre.

3. Chinese or East Indian rhubarb, termed in commerce *half trimmed or untrimmed* rhubarb, rarely presents an angular character, but occurs in rounds or flats. "The best pieces are heavier and more compact than those of the Russian kind, and the odour is much less powerful and less aromatic."

4. Himalayan rhubarb is not known as a commercial article in this country, nor is it even an article of large consumption in India, where it sells for only one-tenth of the best rhubarb, resembling in quality the Russian, and which is found in India. The finest Russian rhubarb might be introduced and cultivated in the territories of the East India Company, or, as Dr. Royle observes, "a trade in rhubarb with Tibet or Western Mongolia might be established by means of the Tartars who resort to the hill fairs. This trade might easily be encouraged by the government purchasing all the rhubarb it requires, which might thus be employed for hospital use after crossing the frontiers, instead of, as now, after making a journey of 20,000 miles, or nearly the circuit of the globe." ('Flora of the Himalaya.')

5. English rhubarb occurs in two states, "*dressed or trimmed*, so as to resemble the Russian kind, and *stick* rhubarb. The first is grown at Banbury in Oxfordshire, and is frequently used for the show-bottles in druggists' windows, and often sold in the streets of London for *Turkey rhubarb*, by persons dressed up as Turks. Stick rhubarb is sold in the herb shops, and is in long pieces."

6. French rhubarb is not brought into this country.

What is termed *Monk's rhubarb* is not the produce of any species of *rheum*, but of the *Rumex alpinus*, which grows in Switzerland, Germany, and Mount Taurus, and is more astringent than purgative: it is mostly used by the monks of the Alps, or to adulterate the other sorts.

Large importations of rhubarb are made into this country, partly from Russia, but much more from the East Indies; but the greater part is for re-exportation. The quantity retained for home consumption scarcely constitutes one-fourth of the entire amount.

Rhubarb presents the peculiarity of producing two opposite effects, according to the dose exhibited. In small doses it is tonic and astringent, in large doses purgative, but generally followed by constipation. It is moreover somewhat heating, and therefore unfit for the early stage of inflammatory diseases; on the other hand, its tonic properties render it eminently proper in the later stages of these diseases. In debility of the digestive organs, alone, or better in conjunction with other agents, it is a most valuable remedy; but it is very improper in the form of powder for very young children, as the insoluble woody fibre irritates their delicate stomachs, and contributes to produce that state of irritation under which so many young children sink who are overdosed with domestic medicines. Dr. Reid, from large experience at a public dispensary, stated it as his deliberate opinion, that half the children which died in London under two years of age were killed by mothers and nurses dosing them with rhubarb and magnesia. A more rational proceeding is to regulate the diet of tender infants, especially of such as are not suckled by the mother or a wet nurse; above all, to avoid giving them stimulating drinks or raw fruits. Where any form of gentle aperient and antacid is really necessary for children or infants, an infusion of rhubarb made with cold water, to which carbonate of soda is added, answers well. Compound rhubarb pill, a very commonly-used aperient, is hurtful to persons prone to suffer from piles. But an unobjectionable and very mildly acting aperient pill can be made with equal parts of extract of rhubarb, extract of jalap, and extract of taraxacum, with a very little jalapina, and some drops of any volatile oil, such as dill, carraway, or cloves.

Several species of rheum, and garden varieties of them, are cultivated for the sake of the petioles of the leaves, which are much used to make tarts in spring. The cooling and gently aperient properties of these render them grateful and beneficial to most persons; but individuals prone to calculous complaints should carefully avoid them, and all vegetables which owe their acidity to oxalic acid, as the formation of the oxalate of lime, or mulberry calculus, may be the consequence of indulgence. This observation applies equally to the species of Rumex which are used as sorrel. [CICER ARIETINUM.] (Pereira's 'Mat. Med.')

RHEUMATISM (from ῥευματισμὸς, "a defluxion"). It is probable that this term was originally adopted during the prevalence of the doctrines of the humoral pathology, when every disease attended with swelling was attributed to the flow of some morbid humour to the part affected. Before the year 1642, rheumatism and gout were usually described as one disease, under the name of arthritis; the distinction between the two is said to have been first accurately made by Bellonius, a physician who suffered much from rheumatism.

Acute rheumatism, called also rheumatic fever, has been so well described by Sydenham, that we make use of his own words: "This disease," he observes, "happens at any time, but especially in autumn, and chiefly affects such as are in the prime of life. It is generally occasioned by exposing the body to the cold air immediately after having heated it by violent exercise or some other way. It begins with chilliness and shivering, which are soon succeeded by heat, restlessness, thirst, and the other concomitants of fever. In a day or two, and sometimes sooner, there arises an acute pain in some or other of the limbs, especially in the wrists, shoulders, knees; which shifting between whiles, affects these parts alternately, leaving a redness and swelling in the part last affected. In the beginning of the illness the fever and the above-mentioned symptoms do sometimes come together, but the fever goes off gradually, while the pain continues and sometimes increases." Acute rheumatism varies considerably in intensity and duration; the patient may have great fever, and severe pain in nearly every joint, so as to render him perfectly helpless; or the fever may be slight, and the local inflammation limited to one or two joints. There is not always a relation between the severity of the local symptoms and the constitutional disturbance. The duration of this disease is much the same under any mode of treatment; it may be terminated in a few days, or may endure as many months; in nearly every case the general symptoms cease before the local inflammation is stopped. Acute rheumatism simply, is seldom if ever a fatal disease, but complicated with pericarditis, endocarditis, or pleurisy, it is highly dangerous. It behoves us therefore in every case of rheumatism to be on our guard against these complications; they are so frequent and come on so insidiously, that a recourse to the aid of the stethescope should never be neglected. [HEART, DISEASES OF THE.]

With respect to what is called chronic rheumatism, it may be either a continuance of acute rheumatism in a milder form, or may originate in this chronic, or, more properly speaking, subacute character. In either case all the characters of acute rheumatism are present, but in a less violent degree; thus, there is a quickened pulse, some increased heat of skin, a furred tongue, and loss of appetite and sleep, the febrile action undermines the general health, while the local inflammation, although indolent, disorganises the joints. This state of things may endure for an indefinite period, or the febrile symptoms may after a time disappear and the morbid action in the joints cease, not however without leaving behind them such ravages as require a special local treatment. Dr. Elliotson has distinguished chronic rheumatism into hot and cold: in the former, the joints affected are above the natural temperature of the other parts of the body, and are relieved by the application of cold; in the latter, the contrary is the case. Whether the pain of the joints is relieved most by hot or by cold applications, it is generally aggravated in cold moist weather, and diminished during an opposite condition of the atmosphere. The only diseases with which rheumatism can be confounded are gout and periostitis; for its distinction from the former of which see GOUT.

The term rheumatic, whether properly or not, has been applied to various affections which have very little resemblance to one another, except in being attended with pain. Thus a class of cases has been called rheumatic gout. This is a disease partaking of the characters both of gout and rheumatism. It may be rheumatism attacking the small joints, or it may be gout extending to the large; in either case the distinction is not of much importance, as the treatment is the same.

When rheumatism is seated in the back, it is called lumbago, from *lumbus*, the loin; when in the back of the neck, the patient is said to have a stiff neck, or a "crick in the neck;" when in the head, one half only is usually attacked, and it is called hemicrania. When the pain occupies the more fleshy parts of the limbs, as the muscles or their aponeuroses, the term rheumatalgia is sometimes made use of. In this last-named affection there is neither redness nor swelling, and pain is experienced only when the muscles of the part affected are called into action. Many persons believe that the nerves themselves may be affected with rheumatism, and refer to sciatica and hemicrania as examples. In these cases the pain is generally of an intermittent character. This intermittence of pain is not peculiar to nervous rheumatism, but is met with also when the aponeuroses of muscles are the seat of the disease, as in hemicrania. "It usually attacks one half of the organ (the head), and the pain generally comes on in the evening about six o'clock, and continues very violently for a few hours. Occasionally when it is intermittent in this way, the parts are hot, swollen, and throb, and the eyes water; but in other cases this is not felt." (Elliotson.) Many physicians of eminence deny that the above-named affections are rheumatic, and consider them to be of nervous origin; hemicrania and lumbago they call neuralgia, and rheumatalgia they designate by the term myositis. From this contrariety of opinion we may conclude that little is known respecting the structures actually affected in these varieties of rheumatism; of the morbid changes which they undergo we are likewise in equal ignorance. In the true or articular rheumatism it is the synovial membrane lining the cavity of the joints and the fibrous tissues external to them that principally suffer. The respective degree in which each of these structures is implicated is not the same in every case. Thus, in one case, we shall find the joints distended with fluid, the fluctuation of which is very perceptible to the hand; while in another there shall be swelling, but it will be more diffused and without fluctuation, showing that little or no effusion has taken place into the joint, but that the swelling results from the inflammation of parts external to it. This difference has led some persons to speak of rheumatism as fibrous and synovial; but inasmuch as it is not always easy to determine to which variety the case under examination may belong, and is besides of no practical importance, the distinction is not usually regarded. The fluid which is found in the joints may be either gelatinous or purulent, according to the severity of the inflammation. The synovial membranes which line them are red and thickened; the ligaments external to the joints are thickened and rigid, the limbs frequently contracted, and the muscles wasted. In rheumatic gout there is often found a deposit of lithate of soda in the joints affected,—a proof that, in many cases at least, this disease partakes more of the character of gout than of rheumatism. The appearances presented in the heart and its coverings, where this organ has been attacked, have already been described in the article HEART, DISEASES OF THE.

Causes of Rheumatism.—Among the causes which predispose to rheumatism must be placed an hereditary tendency and the age and temperament of the individual. The period of life most subject to acute rheumatism is from puberty to 35 years of age, and persons of full plethoric habit are said to be more liable to its attacks than those of an opposite temperament. It is supposed by many, among whom may be cited the names of M. Andral ('Anatomie Pathologique'), M. C. Roche ('Dictionnaire de Médécine et de Chirurgie), and Dr. Barlow ('Cyclopædia of Practical Medicine), that an absolute or relative condition of plethora is essential to the development of rheumatism; and the blood, according to these authorities, may be either excessive in quantity or altered in quality. "There are some individuals," observes M. Andral, "who naturally make a greater quantity of blood than others. When the bloodvessels contain a greater proportion of the nutritive fluid than is necessary to supply the demands of the different organs, the superabundant quantity becomes a permanent source of excitation to the solids, and at the same time the blood has a remarkable tendency to accumulate in different organs; so that in such a case the whole system is in a general state of excitation, and some of the organs may become the seat of local congestion of various degrees of duration and intensity." In applying these doctrines to the disease we are considering, he observes, "If we mark the symptoms and progress of acute rheumatism, we find that very often a well-marked febrile action, with a strong reaction, but without any symptom whatever of local affection, precedes the pain. In a word, there is first an inflammatory fever, and then rheumatism. Next observe the extreme mobility of the rheumatic pains. They run along, in a manner, wherever the blood is distributed; the application of leeches often removes the pain from one part, but it soon shifts to another, and not unfrequently it quits the articulating tissues and fixes on different internal organs, producing, by the derangement of their functions, symptoms more or less severe. It often happens that bleeding from a large orifice puts an end to the disease, as if, by diminishing the mass of blood, it proportionally diminished the stimulus that promoted all these shifting irritations." It is then, when the body is in this predisposed condition, from any of the before-mentioned causes, that exposure to a continued draught of cold air or a shower of rain becomes the immediate exciting cause of an attack of rheumatism.

Whatever may be the general condition of plethora, which has been observed in certain cases, there can be no doubt that rheumatism will only come on in certain conditions of the blood. It has been observed that during rheumatism considerable quantities of lithic acid and lithate of ammonia occur in the urine, and there seems to be little doubt that in all cases of rheumatism there is an accumulation in the blood of some substance which acts as a *materies morbi*. This substance is not identified, but between the substances of the food on the one hand and the excretions of the skin and kidneys on the other, there is a wide field for the production of abnormal products, which may be the cause of disease. It has been supposed by Dr. Todd and others, that the real *materies morbi* is lactic acid in the blood. This, however, is at present problematical, but it is very certain that an abnormal condition of the blood is the most general antecedent of rheumatic disease.

Cold has been often supposed to be an absolute cause of rheumatism. But this is certainly not the case, as out of half a dozen men exposed to the same degree of cold only one may have rheumatism. This disease is also not more prevalent in hot climates, as compared with cold ones, than could be accounted for on the supposition of other causes than cold producing the disease. That cold is an exciting cause when the body is already predisposed there can be no doubt.

Treatment of rheumatism.—Dr. Haygarth, on being asked what was the best remedy for acute rheumatism, is said to have replied, "Six weeks." The sagacity of this reply can be best estimated when the literature of acute rheumatism has been gone through. Blood letting, calomel, opium, bark, alkalies, iodide of potassium, colchicum, aconite digitalis, tartarised antimony, nitrate of potash, brandy and water, infinitesimal doses,—have all had their advocates, and in every set of cured cases reported the average duration will be found to be about six weeks. It is not, however, to be supposed that the treatment of acute rheumatism is one of indifference. According to the severity of the symptoms and the temperament of the individual the judicious physician will apply his treatment. The symptoms of disease of the heart should be watched for with anxiety, and where detected the treatment must be modified accordingly. Blood-letting is now seldom had recourse to. Opium to alleviate great pain and alkalies to act on the kidneys and bowels, and modify the condition of the blood, are recommended by all rational practitioners. Dr. Bennett, of Edinbergh, speaks highly of nitrate of potass. Local bleeding is occasionally of service. In chronic rheumatism liniments over the inflamed joints, with iodide of potassium, and bark, and guaiacum, with other tonics and stimulants, are valuable remedies. Cold bathing and mineral waters are adapted for some cases.

According to Dr. Elliotson, whether rheumatism be acute or chronic, the treatment should be exactly the same: "You have only to make two distinctions,—to ascertain whether it is the inflammatory form of the disease: whether the parts are hotter than they should be, and heat does harm; or whether the parts are cooler than they should be, and heat does good." In the one case he recommends antiphlogistic measures, and in the other stimulants; under the antiphlogistic measures, he comprehends bleeding and the administration of colchicum, the latter to be continued till it purges the patient. During the whole time of the treatment cold, lotions are applied to the inflamed joints. In the chronic form of rheumatism the joints are kept hot with flannels and rubbed with stimulating ointments and liniments, while the ammoniated tincture of guaiacum, beginning with half-dram doses, is given three times a day. Dr. Elliotson also considers that mercury is occasionally useful in both kinds of rheumatism. Lumbago and sciatica are most successfully treated by cupping the loins and the parts over the course of the great sciatic nerve, followed by the application of blisters to the same regions, and a general antiphlogistic regimen. In hemicrania great relief is frequently obtained by the application of heat to the part affected, as in wrapping up the head in flannel. Should the pain evince a tendency to return every evening, a large dose of a narcotic should be administered just previous to the paroxysm, and if not relieved in two or three hours, a similar dose must be repeated; we are informed that one grain of stramonium for an adult frequently acts like a charm in this affection. In rheumatalgia, when the parts are not hot, and the pain is not increased by heat, acupuncture and shampooing have been found of great service.

Where the joints are stiff and contracted, from long-continued inflammation, warm bathing, combined with frequent and persevering exercise of them, have been attended with the most signal success.

(Sydenham, *Opera Medica*, 'Tractatus de Podagra et Hydrope;' Andral, *Anatomie Pathologique*; C. Roche, *Dictionnaire de Médecine et de Chirurgie*; Dr. Barlow, *Cyclopædia of Practical Medicine*; Dr. Elliotson, *Practice of Medicine*; Dr. Bennett, *Principles and Practice of Medicine*. Dr. Fuller, *Rheumatism and Rheumatic Gout.*)

RHEUMIN. [CHRYSOPHANIC ACID.]

RHODALLINE. [THIOSINAMINE.]

RHODANHYDRIC ACID. Synonymous with HYDROSULPHOCYANIC ACID.

RHODANOGEN. Synonymous with SULPHOCYANOGEN.

RHODEORETIC ACID. [CONVOLVULIC ACID.]

RHODEORETIN. [CONVOLVULIN.]

RHODEORETINOL. [CONVOLVULINOLIC ACID.]

RHODEORETINOLIC ACID. [CONVOLVULINOLIC ACID.]

RHODIUM (Ro), a metal discovered by the late Dr. Wollaston in 1803, and named from *rhodon* (ῥόδον, a rose), on account of the colour of one of its solutions. This metal exists in combination with platinum. According to the analysis of Berzelius, the ore of Columbia contains nearly three and a half per cent., and that of Siberia only 1·15 per cent of rhodium. When the greater part of the platinum and palladium have been separated from the solution of the native grains, by the addition of chloride of ammonium and cyanide of mercury, a plate of iron is to be immersed in the residual solution, and by this the rhodium, with small quantities of platinum, copper, and lead, is thrown down in the metallic state. In order to render the rhodium pure, it is first digested in dilute nitric acid, which dissolves the copper and lead, and the rhodium and platinum are then to be dissolved in aqua regia mixed with some common salt, and the solution is to be evaporated to dryness. By this operation there are obtained the double chloride of platinum and sodium, and rhodium and sodium. The former is to be dissolved in alcohol, and the latter afterwards in water, when a plate of zinc immersed in the solution precipitates the rhodium in the metallic state. The metal thus procured is in the state of a black powder, and requires the strongest heat of a wind-furnace, or better the oxyhydrogen blowpipe, for fusion. It is less fusible than platinum.

Rhodium is white; has a metallic lustre; is extremely hard; specific gravity 12·1; and is ductile and malleable. It is not dissolved by any acid or by aqua regia, except when it is alloyed by other metals; and this circumstance accounts for its being dissolved, when alloyed with platinum, in the native grains of this metal. It suffers no change by exposure to air, either dry or moist. The equivalent of rhodium is 52·16.

Oxygen and Rhodium form two compounds. They cannot be made to combine by direct action. The protoxide has not yet been obtained in a state of purity. When finely-divided rhodium, mixed with potash and a little nitre, is heated to redness in a silver crucible, the metal is oxidized, and becomes of a brown colour, and is mixed with potash; the mass is to be washed with water and then treated with hydrochloric acid, by which hydrated peroxide of rhodium is left, of a greenish gray colour. It contains Ro_2O_3. When this peroxide is heated, it becomes black, and is then probably converted into protoxide.

Chlorine and Rhodium probably unite in three proportions, but the perchloride (Ro_2Cl_3) only has been hitherto obtained in a separate state. It was procured by Berzelius by adding silico-hydrofluoric acid to a solution of the chloride of potassium and rhodium, as long as the double fluoride of potassium and silicon was generated, after which the filtered liquor was evaporated to dryness, and the residue redissolved in water. The remaining perchloride thus obtained has a dark brown colour, and when heated to redness, chlorine is evolved and metallic rhodium obtained. The aqueous solution of this salt is a fine rose-red colour, whence the name of the metal which it contains.

This salt forms double compounds, called rhodio-chlorides, with the chloride of potassium and of sodium.

Sulphur and Rhodium may be made to combine by heating them together, the metal being in a state of minute division. The *protosulphide* ($Ro\,S$) formed fuses at a white heat without decomposition, has a bluish-gray colour, a metallic lustre, and by the action of nitric acid is converted into sulphate of rhodium. *Sesqui-sulphide* of rhodium (Ro_2S_3) may be formed by heating the ammonio-chloride of the metal with sulphur, or by heating its solution with sulphide of potassium.

Salts of Rhodium.—The salts of the peroxide only have been formed. Their general properties are but little known.

Nitrate of Rhodium is obtained by dissolving the peroxide in the acid: it is of a deep red colour, and uncrystallizable.

Sulphate of Rhodium is procured, as already mentioned, by acting upon the sulphide with nitric acid. The solution is of a deep red colour, and does not yield crystals. When the caustic alkalies are added to the solution of this or the other soluble salts of rhodium, a precipitate of the hydrated sesqui-oxide of a greenish-yellow colour is obtained after some time; the alkaline carbonates produce no effect, nor does sulphurous acid, nor the ferro-cyanide of potassium. Hydro-sulphuric acid throws down sulphide of rhodium; but the hydrosulphates of ammonia and potash produce no immediate precipitate.

Alloys of Rhodium.—When combined with steel to the amount of only two per cent., it gives the steel great hardness without causing it to crack under the hammer. Dr. Wollaston examined several of its alloys, and, on account of its hardness, he suggested its employment for the nibs of metallic pens; to which purpose it has been applied successfully. It has not been combined with mercury.

RHODIZONIC ACID ($3HO, C_7O_7$). In the preparation of POTASSIUM, a combination of that element with carbonic oxide is formed in considerable quantities. The composition of this compound is not at present very well understood. In the presence of moisture, however, it assimilates water, and is converted into the potash salt of an acid termed *rhodizonic* (ῥόδον, a "rose"), from the red colour of its salts. Rhodizonate of potash forms oblique rhomboidal prisms of a bluish-green metallic appearance. It is insoluble in alcohol or ether, but readily soluble in water, yielding a deep red solution; it is inodorous, tasteless, and tolerably permanent in the air. On the addition of sulphuric acid to the potash salt, rhodizonic acid is set free, and may be obtained in bluish-black crystals.

Croconic acid ($2HO, C_{10}O_8$), so called from the yellow colour of its salts, is a product of the action of a temperature of 212° Fahr. upon rhodizonate of potash. From the potash salt the acid may be set free by sulphuric acid, or, better, *hydrofluosilicic acid*. It crystallizes in transparent, orange-yellow, inodorous, astringent, and very acid crystals.

It is soluble in water or alcohol, and forms neutral or acid salts with bases.

RHODOTANNIC ACID. [Tannic Acids.]

RHOMB, RHOMBUS, RHOMBOID. These terms have been used in various significations by different writers, and the second and third have been sometimes distinguished from each other in meaning. It is not worth while to do more than state, that when either of them is now used, it signifies an equilateral oblique parallelogram. The Latin dictionaries define rhomboides to be a parallelogram, and rhombus an equilateral parallelogram.

RHUBARB. [Rheum.]

RHUBARBARIC ACID. [Chrysophanic Acid.]

RHUBARBARIN. [Chrysophanic Acid.]

RHUMB. [Rumb.]

RHYME. Johnson derives this word from the Greek *rhythmus* (ῥυθμός). Others derive it from the Swedish and Danish *rim*, the Dutch *rym*, and the German *reim*. All the principal European nations use the same word to signify the same thing. Thus, the French have *rime*, the Italians *rima*, and the Spaniards *rima*. The Greek and Roman poets did not use rhyme, and the word rythmus was applied by both, in its poetical meaning, to the metrical arrangement of syllables, and not to the correspondence of sound in their terminations. Rhyme was not used either by the Celtic or by the early Scandinavian nations. Thus the Irish and Erse poems on which Macpherson founded his 'Poems of Ossian' are without rhymes, as is also the Scandinavian poem of the 'Lodbrokar Quida' (Lodbroc's Death-Song). Rhyme, as an accompaniment of verse, cannot be traced farther back among European nations than to the *rymours* of Normandy, the *troubadours* of Provence, the *minnesingers* of Germany, and the monks, who, after the fall of the Roman empire, added rhyming terminations to the Latin metres which were chanted or sung in the church service. Rhyme was early employed by the Italian poets. The 'Divina Commedia' of Dante, the oldest of the great Italian poems, is in alternate rhymes. The early Spanish ballads sometimes have rhymes, sometimes only assonances [Assonance], and sometimes, as in the old Spanish romance of 'The Cid,' are without either rhyme or assonance. The early Anglo-Saxon poetry is without rhyme, but it is sometimes used in the later. All the old English poetry has rhymes, which are rude and imperfect, like the versification, but they are obviously an adjunct to the verse which could not be omitted.

Perfect rhymes arise from the identity of sound with which different words terminate—the identity, not the similarity. In monosyllables, or words which have the accent on the last syllable, to constitute a perfect rhyme it is necessary that the sound of the last accented vowel and of any letters which may follow it should be exactly the same as those of the word with which it rhymes. The sounds which precede the last accented vowel must be different in the two words. The spelling is of no consequence; the rhyme is in the sounds, not in the conventional signs by which the sounds are expressed. Thus *no* rhymes to *so*, but not to *do*, which rhymes to *too* or *two*; *great* rhymes to *hate*, but not to *heat*, which rhymes to *feet*; and so on. If the sounds of the last vowels, or of any of the following consonants, differ in any degree, however small, the rhyme is so far imperfect; thus, *love* and *move* form an imperfect rhyme, the sound of the *o* in love being not only shorter than that of the *o* in move, but to a certain extent different. These monosyllable or last-syllable rhymes are called male rhymes.

Another class of rhymes is formed from words in which the accent is on the last syllable but one. In this class it is requisite that the sounds of the last vowel in the last syllable but one and of all the following letters should be the same as those with which they rhyme. Thus, *desiring* and *respiring*, *descended* and *extended*, are perfect rhymes of this class. These are called female rhymes.

The principle of rhyming, once understood, the application is easy in all cases. Thus, if the accent is on the last syllable but two, the sound of the last vowel of the last syllable but two, and of all the following letters, must be the same. Thus, *sensible* and *extensible* are perfect rhymes of this class, but *dissolute* and *resolute* are imperfect rhymes, the vowels in the last syllable but two of both words having different sounds.

The same principle of rhyming applies to all the modern languages, as well as to the English. Imperfect rhymes are more or less freely used in all of them, according to circumstances. The English and German languages, which abound in consonants, and have for the most part consonant terminations, are more deficient in rhymes than the Italian and Spanish, which abound in vowels, and have for the most part vowel terminations.

RHYTHM (Ῥυθμός, *measure, proportion*), in Music, is *Time*; first, in a limited sense, as in the relative proportions of notes in a single bar; and, secondly, in a more general sense, as in the relative proportion of a number of bars in any given portion of a composition, as in either half of a minuet or of a march. Rhythm is the most important constituent of music; without it inarticulate sounds are unproductive of any musical effect. [Music.] In melody, that is, a succession of measured sounds, notes are the component parts of a bar, and bars are the component parts of a strain, or musical period, or phrase. The due relative proportion of all these is absolutely necessary in the formation of a good musical composition; without it, says one who seems to have possessed a most discriminating and refined taste in the art,—

> "How sour sweet music is
> When time is broke, and no proportion kept!"
> *Richard II.*

Musical *Rhythm*, in its limited sense, divides a bar into 2, 4, 8, &c. or 3, 6, 12, &c. equal parts; the former is *binary* measure, the latter *ternary*. In its more general sense it divides a strain, a phrase, or by whatever name the subdivisions of a composition may be designated, into equal portions of 2 or 4, &c. or 3, 6, &c. bars, or measures; and some writers have admitted a rhythmus of five bars. An intimate acquaintance with the nature of rhythm, whether considered in its relation to music or poetry, is essential to the accomplished composer; without a full knowledge of this he is perplexed by doubts, and guilty of errors which have too often brought reproaches on the art, when they ought to have fallen on the pseudo-artist. Our limits however will not allow us to extend this article; and we refer the reader, particularly the professional one, to a learned and able disquisition on rhythm in Burney's 'Hist.', vol. i., p. 71; to Callcott's 'Musical Grammar,' where much practical information from Riepel and other German writers is to be found; to Kollman on 'Harmony;' and more especially to Reicha's 'Traité de Mélodie.' [Phrase; Time.]

RIBBON MANUFACTURE. Ribbon, or riband, signifies a long narrow web of silk worn for ornament or use. Ribbons of linen, worsted, gold, or silver thread were formerly included in the term, but the designation is now generally confined to those made of silk. Ribbon, in German, is *band*; Danish, *baand*; Swedish, *band*; French, *ruban*; Dutch, *lint*; Russian, *lenta*; Spanish, *cinta*; Portuguese, *fita di seta*, from the Latin *vitta*; Italian, *del nastro, fettuccia*.

Silk was early wrought into ribbons. They formed a branch of the silk manufacture during its progress from Greece to Sicily, and from thence to Italy and Spain; but the ribbon trade seems first to have assumed distinct importance in France. Paris, Tours, Lyon, and Avignon were the chief seats of the trade; the two last cities were rivals until the year 1723, when, partly owing to the regulations which the jealous Lyonnese had prevailed upon the government to make in their favour, and partly to a plague of two years' continuance, the trade of Avignon was ruined, and in great measure transferred to Lyon. Figured ribbons were made chiefly at Paris. About the year 1680, there was a rage for ribbons *gauffrés*, or embossed, on account of their novelty. The stamping was performed by hot plates of steel, on which a pattern was engraved, being applied successively along the piece. A master-weaver named Chandelier, tired of this slow process, contrived a machine which would save his labour. He engraved his figures on two cylinders of steel, between which, when heated, the ribbon was compressed and drawn rapidly by simple machinery: so that a piece of ribbon was embossed in less time than his brother workmen consumed over a single ell. The ribbons called *double lisse* (double warp), which were considered the richest and best, were made at Tours. Before the revocation of the Edict of Nantes, the ribbon-looms of Tours amounted to 3000; but this measure, which banished the Protestants, banished with them their trade, and both Tours and Lyon suffered severely from its effects; the trade of Lyon afterwards revived. Savary, inspector-general of French manufactures, in his 'Dictionary,' published in 1723, says, that the trade in ribbons was much diminished in his time; but it became very large in the next generation. In the enumeration of the different kinds of ribbon, a double satin is mentioned, that is, one alike on both sides in texture, although sometimes of different colours.

Coventry is the head-quarters of the English ribbon-trade. The weaving is done on several systems. The *undertaking system* applies now only to the single-hand trade in the country districts—Bedworth, Nuneaton, Hartshill, &c.: it is the same that the French have employed since the days of Colbert. According to this plan, the undertaker, or master-weaver, receives the silk dyed in the hank from the manufacturer, and returns it in finished ribbons to his order; all the intermediate operations being included in the price of weaving, two-thirds of which are paid to the journey-hand for his labour. Three-fourths of the single-hand weavers are women, and nearly one-half of the remainder are youths under 20. Boys and girls are considered competent weavers at 16 or 17. On the *journey-work system*, by which the great proportion of the engine looms in Coventry and its neighbourhood are worked, the manufacturer gives the silk, already wound and warped, to the first-hand journeyman, who is also the owner of the looms. The shoot-silk is given in hank, for the winding of which the manufacturer allows 1*d.* per oz., besides the price for weaving, in which is included the filling, or the winding of the shoot on the small revolving pins within the shuttles. About one-fourth of the hands employed on this system are women. On the *hand-factory system* the manufacturer is the owner of the looms. The journey-hands work them in the loom-shop of the proprietor, who gets the winding and warping done at his own charge, leaving only the filling to the weaver, which is included in the price of his work, and is often done by very young children. This plan is adopted by many manufacturers of small capital, who, by personally superintending the work, and becoming in fact their own undertakers, are enabled to economise to the utmost in the cost of production; while their hands are all reduced to the lowest condition of the weaver—the journey-hand, who supplies the labour, and has no property in the looms. A modern innovation, encouraged by the last system, is the employment of two hands to a loom, the one being occupied uninterruptedly in shooting down, or passing the shuttle, and making the ribbon; the other in picking up, or fastening broken threads, picking out knots, &c. On the *steam-factory system*, the manufacturer gets every preparatory process done, and by the steam-power one-half of the weaving process itself—the shooting down: all that is left for the weaver being the picking up and superintendence. The profitable application of steam-power to silk-weaving was long considered to be almost impossible, so large a portion of time being consumed in the handling and trimming of the silk, in proportion to the time that the loom is in motion, and a consequent waste of power. A small factory was built in Coventry in 1831, for the purpose of making the experiment on ribbons. It was burnt, however, during a disturbance relating to prices; but within a few years there were numerous steam-factories at work at Congleton, Leek, Derby, and other places, which made large quantities of plain ribbons, chiefly black sarsenets. The Coventry manufacturers had more difficulties to contend against, but ultimately they introduced steam-power under certain circumstances. In these power ribbon-looms, each loom is tended by one pair of hands, which pick up and keep the machinery in order. The gain consists, not in a more rapid motion of the shuttles, the delicacy of the materials not allowing of this, but in the shooting down being seldom interrupted during the picking up, as in hand-loom weaving; in the greater regularity of the fabric, the same number of shoots to the inch being uniformly maintained; and also in the addition of more shuttles, for which one workman suffices, the loom being so constructed as to enable him to reach from the front over the batten to the warps behind.

Italian organzine silk, either thrown in Italy or in England from Italian raw silk (and principally the last), is used for the warp of the best English ribbons: Bengal and China organzine for inferior qualities. China, Bengal, and Broussa (a Turkish silk, produced at Bursa or Brousse, in Asia Minor) singles, all English thrown, are used largely for shoot. Bengal cannot be used for fine colours. Marabout is used for gauzes. Much of the silk-throwing and dyeing is done at Coventry. When the silk is dyed *soft*,—that is, when the gum is boiled off,—it comes back from the dyer with a loss of four ounces out of sixteen in weight; when dyed *single*, the gum being partly retained, it loses only one ounce and a half in sixteen. Inferior warp silk dyed black, and of dark colours, is sometimes *weighted* by an additional quantity of dye, or by a mixture of sugar to increase its apparent substance.

The fineness of the silk is determined by the number of warp lengths, measuring 72 yards, in the ounce; fine warp silk, for instance, runs about eight score threads to the ounce of that length. One ounce in twenty is allowed for waste in the manufacture of the silk into ribbons; for all over that quantity the undertaker, or journey-hand, is accountable. If the warp and shoot are delivered ready wound, a quarter of an ounce in twenty is allowed. The preparation of the silk by winding it from the hanks on bobbins, and then again winding it off from a sufficient number of these bobbins at once round a large revolving perpendicular reel, called the warping-frame, until the requisite length is obtained for the piece of silk or ribbon that is to be manufactured, and likewise the weaving process itself, are the same for the making of ribbons and for broad silk.

The weaving of ribbons is conducted in many different ways. The *single-hand ribbon-loom* differs in no essential respect from that used for any other fabric, except that its size and strength are proportional to the lighter material.

The Dutch *engine-loom* was introduced about ninety years ago. In this loom, instead of one piece of ribbon only, several are woven at once, four of the broadest width, or as many as twenty-four of the narrowest. Each warp has a separate shuttle. The batten extends across the whole width of the loom; the shuttles slide within grooves made in the batten; the driver is worked horizontally backwards and forwards by a handle. At each motion, the shuttles are propelled by the cross-bars of the driver across their proper warps in the corresponding direction. The loom is worked by the hands, and with treadles for the feet, like the single hand. The stroke of the batten is made with more precision than in the single-hand loom, by the interposition of blocks of wood fastened to the framework in front, which resist the batten at the proper point. The impulse of this stroke pushes back the finished ribbon, which is hung with a weight attached to the end over a pulley at the top of the frame, or wound on a roller, just enough to draw forwards the warp, which is similarly hung over a pulley, in order to receive the shuttle at the same point. Each warp has a separate reed or *sleigh* attached to a horizontal roller, over which it passes on descending from the pulley. The sleigh is an instrument like a comb, for keeping the threads separate. There are corresponding sleighs in the batten.

The *à-la-bar*, or *bar-loom*, was invented and introduced into St. Etienne by two Swiss brothers about eighty years ago. It has largely contributed to the prosperity of the place, but the brothers died in poverty and neglect. It is a hand power-loom worked by means of a long transverse handle or bar, which extends along the front of the loom, and is connected with wheels on each side, which communicate the motion. The shuttles are driven by means of a rack and pinion across the warps. The advantage of the bar-loom consists in the saving of labour by the intervention of mechanical means, instead of applying manual power direct to the usual operations of weaving. From twenty-eight to thirty of the narrowest and from six to eight pieces of the broadest width are made at once: about eight ells of the former per day, and from three to four of the latter.

Several hand power-looms for ribbons have been contrived and adopted, in all of which the requisite movements are performed by a combination of levers, springs, cranks, and wheels.

Figures on ribbons, as in other fabrics, are chiefly formed by omitting the regular crossing of the warp and shoot in such a manner that a difference of texture shall occur in the web so as to mark out any pattern. This is effected in the single-hand loom by a multiplication of treadles connected with the lisses by which the different portions of warp are alternately raised. Forty treadles have been sometimes required to form an intricate pattern. Small figures produced in this manner are called *leys*. To execute more complicated patterns, *tires* or *draws* are used. Tires are cords hung over the top of the loom, and pulled by the hand as the figure may require; they work like the treadles, by raising the lisses, through the eyes of which are passed the threads to form the pattern. Small patterns are still largely made in the single-hand looms by means of treadles and tires. The French single-hand loom of this description is called *hautelisse*. This was the name of the loom used in weaving the best tapestry, in which the warp was stretched perpendicularly, and hence it came to be applied to other looms for weaving figures. The production of a large pattern in this manner is difficult and tedious. Many skilful contrivances have been devised by weavers and others for facilitating the operation, and among others the *draw-boy*; but they were all superseded by the introduction of the Jacquard machine. [JACQUARD APPARATUS.]

The work is ordinarily given out in *sets of grosses*, consisting of two warps for each shuttle, each warp containing two pieces of 36 yards. The ribbons are cut out in pieces of 36 yards if they are of satin, and in half-pieces of 18 yards if they are sarsenets or gauzes above the narrower widths. A set of pieces cut out of a loom is called a *length* and a set of half-pieces a *half-length*. The putting in of a fresh set of warps is a tedious operation, which requires from two or three to fourteen days, and proportionally lessens the earnings of the weaver. A simple change of pattern, however, is often effected with very little loss of time. Whenever it is practicable, the ends of the new warp are fastened to those of the old before it is taken out of the loom, whereby the labour of passing them separately through the eyes or mails of the lisses is saved: this is called *twisting in*.

Ribbons are made according to a fixed standard of widths designated by different numbers of pence, which once no doubt denoted the price of the article, but at present have reference only to its breadth. The French distinguish their widths by simple numbers. Thus the English ribbons from a quarter of an inch to about 4½ inches wide are called from *penny* width to *forty-penny* width; while the French have figures from No. 1 to No. 60. All dressed ribbons, as satins, gauzes, &c., are made in the loom one-twelfth of an inch wider than sarsenets, in order to allow for the diminution of breadth which results from the lengthwise stretching they receive in the operation of dressing. Fine gauzes require an allowance of two-twelfths. The French ribbons were made formerly in pieces of 12 ells; their length is now the same as that of the English. French fancy ribbons are generally made and sold in *garnitures*; that is, a broad and narrow piece taken together of the same pattern.

Sarsenet and *lutestring* ribbons are made by the simple and regular alternation of the warp and shoot, as in plain cloth, called technically *ground*. Lutestrings are sarsenets above the width of 12*d*., and in general of stouter make. By *grogram* (French *gros-grains*) is meant a variation in the texture, caused by the warp-threads passing over two of the shoots at once, taking up one only: this often finishes the edge of a ribbon. In *satin* ribbons, the glossy appearance is given by the threads of the warp being laid chiefly on the surface, each thread of the warp being crossed by the shoot only once in five times, as in 5-lisse satin, or once in eight times, as in 8-lisse or the superior satins. French satins were formerly made from 6-lisse to 10-lisse. Satins are woven with the face downwards. The French satins are lighter in make than the English, but have a peculiar richness and lustre, owing to their superior silk. French ribbons in general have less weight of silk than the English. The transparency of *gauze* ribbons is produced by the kind of silk of which it is made—the fine hard-twisted marabout, which leaves the interstices clear. One warp thread only passes between each dent of the sleigh, and these are closer together in general than lutestrings and satins. In fine gauzes, there are 80 or more dents, and from 90 to 120 shoots to the inch. The plain gauze ribbons made at Coventry called China gauzes are chiefly those used for mourning—white, black, and lavender, with satin or ground stripes. *Florets*, *taffeties*, *loves*, and *petershams*, are other kinds of gauze ribbons. These ribbons all belong to the plain trade. The fancy trade comprises the manufacture of the same fabrics figured, under the heads of figured sarsenets, satins, gauzes, &c. The figures are frequently produced in a different colour from the ground by the mixture of colours in the warp, the colours being warped separately. In the intervals of the figures the coloured threads are carried along the under side of the ribbon, it is said to have a *double* or *treble figure*, according to the number of colours passing through each dent. In some ribbons—gauzes in particular—these threads are cut away by the scissors after the ribbon is made. This is called *clipping*. A change of colour in the shoot is effected by the use of different shuttles; in brocades the figure is made by small additional shuttles, thrown in partially across the ribbon as the pattern may require, the connecting threads of shoot being clipped off. By *damask* is meant the laying of the warp over the shoot to form the figure, in the manner of satin. The patterns are sometimes geometrical, but more frequently combinations of leaves, sprigs, or flowers. In the superior French ribbons, groups and wreaths of flowers are executed with the richness and variety of hand-embroidery. The French are continually introducing novelties in colouring and in texture. Some fancy ribbons are of a plain texture, but varied in colouring; they are shot or woven in shades, stripes, bars, or cheques, called in the trade *plaids;* these last, which require the shuttle to be changed very frequently, are still made in the single-hand loom. In *shot* ribbons the warp and the shoot are of different colours. A *pearl-edge* is frequently given to all kinds of ribbon except the narrower widths of sarsenet. This is formed by the shoot passing over horse-hairs placed outside the warp parallel with it, and raised in like manner by the lisses; as the hairs are drawn out, the silk is left in loops at the edge. Many varieties of ornamental edges, as scollops, fringes, &c., are produced by *drawing in*. The shoot in this case stops short of the edge of the ribbon, catching in an additional thread of silk, sometimes of a different colour, which it draws in in its place, and which is delivered from a bobbin at the back of the loom, and is in a manner darned into the ground of the ribbon. *Clouding* is a peculiar management in the dyeing, by which a change of hue is produced in the same thread of silk. The silk, already warped, is tied up and wound closely round with packthread at regular intervals of more or less than an inch, so that the intermediate spaces only are penetrated by the dye. In one species of fancy ribbon, called *Chiné*, the figures are printed or painted on the warp after it is prepared for the loom, and afterwards woven in by the shuttle; others are embossed. Ribbons are *watered* by passing two pieces together between two cylinders, one of which has a heater within it; the irregular pressure of the inequalities of the two surfaces of silk against each other produces a wavy appearance. To smooth and stiffen satin ribbons, they are *calendered*, or pressed between heated steel cylinders, and afterwards dressed, or passed over a small cylinder covered with flannel, which is moistened with a size made from buffalo hides, and then over a large one of heated steel. Gauzes also are dressed, and sometimes even lute-strings. The French goods are in general better dressed than the English. The *blocking* of the finished ribbons, or the winding them on cylindrical pieces of wood, is generally done at the warehouse of the manufacturer. *Galloons* and *doubles* are strong thick ribbons, principally black, used for bindings, shoe-strings, &c. The narrow widths are called galloons; the broader, doubles. Italian silk is used in making the best qualities only, Bengal for the commoner. *Ferrets* are coarse narrow ribbons shot with cotton, used for similar purposes. *Ribbon velvets* are manufactured in Spitalfields, and at St. Etienne: they are also made at Crefeld, in Rhenish Prussia, which has long been a principal seat of the velvet manufacture. In *gold* and *silver* ribbons, a silk thread of similar colour is wound round by a flattened wire of the metal, and afterwards woven. Lyon was at one time particularly celebrated for its fabrics of this kind.

In the ribbon manufacture the labour is nearly the same for the richer as for the inferior goods, the difference consisting principally in the silk of which they are made. Cheap ribbons are generally made by reducing the warp silk, which is the most expensive, and making up the bulk of the ribbon with a larger proportion of the cheaper shoot.

There are certain small wares which may be briefly noticed here, midway in character between *cords* and *ribbons*, and yet more complex than either. These are *gimps, twists, fringes, chenilles*, &c.; in which the results are produced in some few cases by a kind of weaving, but much more frequently by a twisting or looping process. Complicated machines are needed for the production of such goods; and many patents have been obtained for inventions tending to this end. In one contrivance, a looping-machine invented by Messrs. Keely and Wilkins, while one arrangement is suitable for the making of stockings and gloves, another is intended for the making of braids, several at a time, and of one, or of several patterns. A third modification of the same apparatus enables the manufacturers to *plate* or cover any cheap kind of thread with thread of a better sort. A machine invented by Messrs. Hughes and Denham is intended equally for the making of fancy ribbon, fringe, chenille, trimmings, and gimps. There is no actual weaving process adopted, but the appearance of the goods is somewhat as if woven. The apparatus is very complex, consisting of many parts spinning round each other. A ground thread is sometimes formed of wire covered with cloth, or of narrow strips of stiff paper; and the machine will cover these with silken thread. Ornamental trimmings may be made by feeding the machine with strips of tarlatan, muslin, silk, or quilling as a ground, and then winding silk thread round them. Wire groundwork may be used for making chenille; and minor adjustments will furnish the means for making an almost endless variety of fancy goods.

RICE; RICE-MILL. In the article ORYZA, in NAT. HIST. DIV., an account is given of the botanical character, and under ORYZA in the present division the mode of cultivation is described. In order to remove the husk, which adheres very closely, without breaking the grain itself, several ingenious machines have been recently introduced, of some of which it is proposed to give a brief notice.

The common mode of performing this operation in India and China, is by beating the grain in a kind of rude mortar of stone or earthenware, with a conical stone attached to a lever worked by the hand or foot. Sometimes several such levers are moved by arms projecting from the axis of a water-wheel. This process being uncertain and tedious, the preference has been given of late to a kind of mill, in which the stones are placed at such a distance asunder as to detach the shell without crushing the grain; the stones being enclosed in a case which prevents the dispersion of the rice by the rapid rotation of the machine. The rice is thrown out of the case by an opening in its side, and conducted over a sieve that separates the dust; after which it is made to fall in a gentle stream exposed to a current of air, produced by revolving fanners, and thereby separated from the husk. Such a sifting and winnowing apparatus is attached to each pair of stones, and one pair of stones will husk from eight to ten bushels an hour. After the removal of the husk, the grain is exposed to the action of a whitening machine, which removes the inner cuticle, or red skin, remaining on the surface of the grain. This process is aided by the heat generated by the rapid motion of the grains, causing them to swell and split the red skin, which flies off in dust through perforations in the revolving case. With such accuracy are these processes performed, that it is said not more than five per cent. of the grain is broken in the operation.

The method of cleansing rice just described has been practised in Ceylon with British machinery; but other plans have been followed in this country, where, owing to the difference between the duties on cleaned rice and *paddy*, or grain in the rough state, and the better preservation of the flavour of the rice when brought over in the husk, several large rice-cleaning establishments have been gradually brought into operation. The process of Messrs. Lucas and Ewbank consists in breaking the husk by millstones, and removing the red cuticle by beating or triturating in mortars; the latter operation being aided by mixing a quantity of the husks, well dried, with the grain, which obviates an inconvenience occasioned by the glutinous character of the red coating. The refuse matter and the broken grains are then separated by a peculiar kind of screen; and the rice is finally cleaned and polished by a machine with two concentric cylinders, the outer one remaining stationary, while the inner one, which is covered with sheepskin with the wool on, is made to revolve with great velocity. The rice, being placed between the two cylinders, is thoroughly whitened by the friction of the wool.

In the apparatus patented by Mr. Shiel, the first operation is performed between one millstone and a piece of wood of precisely similar shape; and the subsequent removal of the dark pellicle is effected by rubbing between flat wooden surfaces covered with sheepskin. Mr. Ewbank places the wool outwards, Mr. Shiel has it next the wood; its elasticity producing an effect very nearly resembling the rubbing of the grain between the palms of the hands.

Another ingenious contrivance, first used in the United States, consists of a long hollow cylinder of wood, with several bars projecting from its inner surface, and enclosing an axis on which are several other bars capable of revolving between those attached to the cylinder. By suitable toothed wheels the cylinder is made to revolve slowly in one direction, while the axis is turned with great rapidity in the contrary direction. The whole being placed in an inclined position, the paddy is allowed to enter the upper end of the cylinder by a hopper; and the mutual attrition of the grains, as they pass between the revolving bars, causes the separation of the husks, which are removed by a current of air as the grain falls into a bin under the lower extremity of the cylinder. The rice passes out of the cylinder by apertures capable of being enlarged or reduced at pleasure by means of sliding doors; and the action of the machine may be further regulated by varying the inclination of the cylinder, which may be placed vertically or horizontally, though an angle of about 45° is preferred.

Rice is, as is well known, chiefly used as food, but it is also employed to some extent in the arts. A cement is made from it. *Rice-paper* is a name commonly, but erroneously, applied to a delicate vegetable film brought from China in small square pieces, tinged with various colours, and used as a substitute for drawing paper in the representation of richly coloured insects or flowers, and also in the manufacture of artificial flowers and other fancy articles. This substance, a membrane of the bread-fruit tree, though much resembling an artificial production, is evidently of natural growth; for its vegetable organisation is easily seen by the aid of a microscope. Sir D. Brewster, in the 'Edinburgh Journal of Science,' vol. ii., has shown that the rice-paper consists of long hexagonal cells, whose length is parallel to the surface of the film; that these cells are *filled with air* when the film is in its usual state; and that from this circumstance it derives that peculiar softness which renders it so well adapted for the purpose to which it is applied.

The quantity of rice imported into this country varies very much, owing to the fluctuations of the crops. During the last fifteen years it has varied from 269,314 cwts. (in 1845) to 1,744,913 cwts. (in 1858). This was for *home consumption*; there has generally been a still larger quantity imported simply for re-exportation, insomuch that the total import for 1858 was more than 3,600,000 cwts. This is rice, "not in the husk," to use a Customs' phrase. Rice in the husk, or paddy, is entered separately. Before the year 1842, cleaned rice paid a duty of 1*s.* per cwt. if from our own possessions, and 15*s.* if foreign. Since that year the duty on colonial and Indian rice has been lowered from 1*s.* to 4½*d.*; and on foreign from 15*s.* to 4½*d.* The lowering of the duty has been followed by a rapid increase of consumption. Paddy pays a lower duty than cleaned rice.

RICINELAIDIC ACID ($C_{36}H_{34}O_6$). *Palmic Acid.* When ricinelaidin is saponified with boiling potash lye, the soap subsequently precipitated with salt, and then decomposed by hydrochloric acid, ricinelaidic acid separates as an oily body, that solidifies on cooling to a crystalline mass, which may be purified by repeated crystallisation from alcohol. It presents the appearance of silky needles, which redden litmus and are soluble in all proportions in alcohol and ether.

RICINELAIDIN ($C_{75}H_{72}O_{18}$), *Palmin.* A product of the action of hyponitric acid upon castor oil. It is a wax-like body with an odour of hydride of œnanthyl. It is very soluble in alcohol and ether.

RICINOLAMIDE ($C_{36}H_{35}NO_4$). A colourless, crystalline, fusible substance, produced by acting upon castor oil with ammonia. Mineral acids decompose it in the cold, setting ricinolic acid at liberty.

RICINOLIC ACID ($C_{36}H_{34}O_6$), *Elaiodic Acid.* The liquid fatty acid obtained by saponifying castor oil. It is soluble in all proportions in alcohol and ether, reacts acid, and decomposes carbonates with effervescence.

RICINUS COMMU'NIS, the castor-oil plant, known from very ancient times both to the Egyptians and also to the Greeks. According to Herodotus (ii. 94), the Egyptians called the oil of the *sillicyprion* (*σιλλικύπριον*) by the name *Kiki* (*κίκι*). The Greeks also called it *Croton* (*κρότων*), a name bestowed by modern botanists on a closely allied genus of euphorbiaceous plants, one species of which yields the purgative oil designated Croton oil, or Oleum Tiglii. The native country of the Ricinus communis is unknown, though it is conjectured to be originally from Barbary. Like all plants which have been long in cultivation, numerous varieties of it are met with, differing not only in colour and the peculiar pruinose condition of the stem, but in stature and duration. In warm countries it is ligneous and perennial; in cold, annual and herbaceous. The entire plant is possessed of active properties, but the oil extracted from the seeds is only employed in Europe; the ancients administered the seeds entire, but their variable action, occasionally even producing fatal effects, led to their disuse, and the oil is of comparatively recent introduction. The seeds, of which three are found in each capsule, are about the size of a small bean, obtuse at both ends, surface smooth, shining, and beautifully marbled. The skin consists of three tunics—1st, an outer brittle pellicle; 2nd, a hard testa consisting of two dissimilar layers, the external thick, dark brown, formed of transverse radiating cells; the internal thinner, paler, and formed of vertical cells; 3rd, a membrane investing the nucleus or kernel. "The nucleus consists of oily albumen, and an embryo, the cotyledons of which are membranous or foliaceous." The outer shell is devoid of taste; in the inner coat the acrimony or active principle resides, according to Dierbach; while others assert the embryo to be the seat of the purgative principle; and even Humboldt and Bancroft state that if this part be excised, the seeds may be eaten with impunity, or the oil thereafter expressed is as mild as olive-oil. Various procedures have been adopted to extract the oil, and these have much influence on its qualities in respect of colour, acridity, and freedom from rancidity; there are also effects which result from the greater or less maturity of the seeds, the peculiar variety of the plant from which they have been obtained, and the occasionally accidental, but more frequently intentional admixture of other seeds, before the different processes of extraction have been begun. Both in India and America, whence the first supplies were brought, much heat was employed, and during the application of this agent a volatile principle was either liberated, or more probably formed, which was so irritating as to require the workmen to protect their faces by masks. Even in the present day some heat is used to obtain what is termed the *cold drawn* castor-oil, but it is quite unnecessary, and should always be avoided.

According to Sir Whitelaw Ainslie ('Materia Indica,' vol. i. p. 256), the following is the plan pursued in the East Indies:—"Take five seers of the small castor-oil nuts, and soak them for one night in cold water; next morning strain this water off and throw it away, and put the nuts into a second quantity of fresh water, and boil them in it for two hours; after which strain the water off and throw it away, as in the first instance; the nuts then are to be dried in the sun on a mat for three days; at the end of which time they are to be well bruised in a mortar; add to the nuts thus bruised ten measures of water, and set the whole on the fire to boil, taking care to keep continually stirring the contents of the pot until all the oil appears at the top, when it is to be carefully strained off and bottled for use. The quantity of nuts mentioned in this formula ought to yield about one quart bottle of oil." The processes used in the United States and the West Indies are both objectionable, from employing not only heat but water, which last promotes the rancidity of the oil. The acrid property and the rancidity are owing to different causes, the former being always in proportion to the freshness of the oil, the latter to the imperfection of the means used in extracting it, or to its age. The plan adopted in France is the best; it is as follows:—The fresh seeds are bruised, and then put into a cold press (some persons improperly heat the plates of the press). The oil expressed is allowed to stand some time to permit the albumen, mucilage, and other matters to subside, or it is filtered to separate them more rapidly. ('Journal de Pharmacie,' tom. v. pp. 207, 508.) The produce is equal to about a third of the seeds employed, and the oil possesses all its natural qualities. The American process yields only 25 per cent. of oil. In the French West Indian Islands, a peculiar variety of Ricinus, called *R. ruber*, more active, is used, which yields an oil called *carapat*, or *karahat*, but this is violent and unpleasant, and must not be confounded with or substituted for the fine oil procured in France. Both the French and Italian oils are much weaker than oil procured from tropical countries. Another mode of obtaining the oil is to macerate the bruised seeds in cold alcohol, by which six ounces of oil are procured from every pound of seeds. ('Journal de Pharmacie,' viii. 475.) The expense of this process is the objection to its general employment.

Oil of good quality is a thickish fluid, of a very pale yellow colour (the best now almost limpid), with a slightly nauseous odour, and an oily taste, mild at first, but causing a feeling in the back of the throat which is more or less intense in proportion to the freshness of the specimen. Old or badly prepared oil is rancid and disagreeable. The specific gravity is, at 55° Fahr., 0·969, according to Saussure, but according to Geiger it is only 0·954.

It can be solidified only by a very low temperature. It is distinguished among fixed oils by its complete or nearly complete solubility in pure sulphuric æther and in alcohol, thereby approaching the essential oils in its habitudes, and its easy combination with alkaline leys, and consequently its ready saponification, two properties of much importance, the one furnishing a convenient test of its purity, the other facilitating its administration in a form less repulsive than its ordinary state. Its purity may be tested by mixing it with an equal quantity of absolute alcohol, in which it should be entirely dissolved; the adulterating oil, if there be any, will remain undissolved. Its ultimate composition seems to be—

	Saussure.	Ure.
Carbon	74·178	74·00
Hydrogen	11·034	10·29
Oxygen	14·788	15·71
	100·000	100·000

It thus appears to be one of the most highly oxygenated oils or fats, notwithstanding which, on exposure to the air, it very readily absorbs more oxygen, and quickly becomes rancid; it is however slow of drying. It is stated to consist of several proximate principles, but whether these are educts or products is uncertain. Bussy and Lecanu, who have paid great attention to the subject ('Journal de Pharmacie,' xiii. 57) incline to the latter opinion, which is the most probable. "This oil," they state, "cannot be regarded as a simple immediate principle, but as a *compound organic product* resulting from the mixture of at least two different substances." The other view is that it is a compound of *three fatty acids saturated by glycerin*, for in the process of saponification 100 parts of castor-oil yielded—

1. Fatty acids (viz., ricinic, elaïodic, and margaritic acids)	94
2. Glycerin	8
	102

Saalmuler admits only two fat acids and a little acrid resin. These acids are formed during saponification from Ricin-oleine and Margaritine.

The only analysis of the seeds is that of Geiger ('Handbuch der Pharmacie,' ii. p. 1671).

a. Seed-coats	Tasteless resin and extractive	1·91	23·82
	Brown gum	1·91	
	Ligneous fibre	20·00	
b. Nucleus of the seeds.	Fatty oil	46·19	69·09
	Gum	2·40	
	Caseum (albumen)	0·50	
	Ligneous fibre, with starch, &c.	20·0	
Loss (moisture)			7·09
			100·00

For further details respecting the chemistry of castor-oil, see Pereira's 'Mat. Med.,' ii. p. 1287, edit. of 1850.

Castor-oil is a mild aperient or laxative when pure, operating without griping or other inconvenience, and commonly very soon after its administration. It is the most proper laxative for infants, and in many inflammatory states of the abdomen or of the kidneys, bladder, &c. It is also one of the best purgatives in rheumatism, especially in lumbago, and one of the best means of relieving habitual constipation, as, unlike other purgatives, the dose may be successively reduced without its power being impaired. It is also a most eligible medicine in piles or other affections of the rectum. Alone or with turpentine it is a very efficacious means of expelling worms. The chief obstacle to its extensive use is the repulsive taste which it often possesses. Many expedients have been adopted to remove or lessen this; but no artifice can make bad or old oil good or palatable. Rancid oil may be purified by calcined magnesia; but the careful exclusion of the air, which prevents the rancidity occurring, is preferable to any process for removing it when it has affected the oil. Mixing the oil, immediately before swallowing it, with hot milk, coffee, or broth, is sometimes a successful means of escaping the unpleasantness. Besides this the heat not only renders the oil thinner, but quickens its action, so that a less quantity is needed. Thus administered, about one-half the quantity will suffice which is needed when given in any cold vehicle. Brandy and gin are improper in many cases, owing to their heating properties. Syrup of orange and lemon are beneficial adjuncts, especially if a portion of the orange-peel be masticated immediately after swallowing the mixture. An emulsion with yolk of egg is sometimes acceptable, if made immediately before it is administered. By far the best plan however is to take advantage of the tendency to combine with alkalies, and so form a soapy emulsion, which does not destroy the purgative power, while it completely alters the appearance, and prevents any one recognising the oily object of his aversion. To effect this however requires care and skill, especially as a variable quantity of alkaline ley is needed, according to the age of the oil, very old oil requiring more ley than fresh oil. In general from fifteen to twenty drops of pure liquor potassæ will saponify half an ounce of oil, to which one ounce of distilled water, and one drachm of spirit of pimento or of nutmeg are to be added.

Castor-oil is extensively used in the East, France, Italy, and elsewhere, for burning, and lately to make soap.

RICKETS, or Rachitis (from ῥάχις, the spine), is a disease in which the bones being of unnatural softness, some of them bend under the weight of the superincumbent parts of the body. Bones affected with rickets present such a softness of texture that they may be cut with a knife; their walls are remarkably thin, and their interior, instead of being filled with marrow deposited in their bony cells, is occupied by a semi-fluid jelly-like substance of a reddish colour, which fills a number of rounded cavities of irregular size. The quantity of earthy matter in such bones is reduced to considerably less than its natural proportion, and they lose much of their normal weight. All the bones may be thus affected, but it is only those which have to bear the weight of the body that give evidence of it by bending; the arms, for example, never change their form, but the thighs and legs become arched forwards under the weight of the trunk; the spine assumes a variety of curves from the pressure of the head; the breast-bone becomes prominent, and the ribs flattened; the haunch-bones grow outwards, and the pelvis is sometimes seriously deformed by an approximation of its anterior and posterior boundaries.

Rickets, as far as the softness of the bones is concerned, cannot be regarded as a dangerous disease; for this condition is generally recovered from, though not without deformity of the trunk and lower limbs. But the disease of the bones is commonly only a part of a general state of disease affecting many other organs of the body. The muscles are always pale and weak, and there are all the signs of general debility; and besides these, the brain and the organs contained in the chest and abdomen are peculiarly apt to suffer, and become the seat of fatal diseases, such as hydrocephalus, phthisis, obstruction of the mesenteric glands, &c.

The general symptoms present in cases of rickets are so much like scrofula, that many writers treat rickets but as one of the many forms in which scrofula presents itself. [Scrofula.] At any rate, in the treatment of rickets the same general plan is found to be equally efficacious. The causes of rickets are to be sought in an improper diet, and exposure to those conditions of life which prevent a due oxidation of the blood, and an imperfect assimilation of the food. It is more frequent in children living in large towns or overcrowded villages, than amongst those who obtain healthy food and pure air. One of the most important elements of treatment is the removal of the patient from any overcrowded district in which it has been living into the country, where it can have pure air, and if possible sea air. In young children, fresh cow's milk, with baked wheaten flour, and meat teas, should be administered. Cod-liver oil should be given as medicine, and cream may be added to the cow's milk, and butter may be freely taken with the food. The deficiency of phosphate of lime may be repaired by the administration of jellies made from ivory or bone dust, which may be made palatable with spices and sugar.

When rickets affects only or chiefly the bones, an attention to the means just mentioned will, with advancing age, usually lead to a termination of the disease. The bones will gradually become hard by the addition of their natural quantity of earthy matter. They retain indeed the curves which they acquired in their condition of softness, but the want of strength which might result from this change of form is compensated by the remarkable thickness and strength which they acquire in the concavities of the curves, upon which the chief stress from the weight of the body falls.

Young persons are exclusively subject to rickets. It occurs at the age of two or three years, and from that time to puberty, and as the curvatures begin to form as soon as the weight of the body is thrown on the limbs by assuming the erect posture, it is commonly proposed to support the upper part of the body and the limbs by *irons*. Such measures however are, in a large majority of cases, full of mischief; if they can ever accomplish their intention of supporting the head and trunk, it can only be by preventing entirely that active use of the limbs which is essential to the attainment of the proper hardness of the bones. It is constantly observed that the strength and density of bones are in direct proportion to the habitual exertion of the muscles attached to them; and as the latter are made inactive by irons, the application of any such modes of restraint cannot but be injurious to those affected with rickets.

When children first begin to walk, their legs not unfrequently become a little bent. This is especially the case with those that are large, and have heavy bodies to bear; but it is not to be regarded as a sign of rickets, and when the muscles of the limbs become stronger, and the bones in their natural process of development grow harder, the curvatures will gradually disappear. The distinction between this kind of bending of the legs and that dependent on rickets may be made by the condition of the general health in each; in the former it is unaffected, or may even be more than usually good, in the latter it is always weak and disordered.

RICOCHET, a word expressing the act of rebounding, is applied to the mode of firing ordnance in which (the axis of the piece being parallel, or inclined at a small angle to the horizon) the shot or shell, having described a curve in the air, descends to the ground, and, after striking or grazing it, rises upwards; when, by the force of the impulsion, and the power of gravity, it describes a second curve of small elevation; the shot, then descending as before, again grazes the ground, from whence it experiences a second reflection. This effect frequently takes place several times before the force of impulse is destroyed.

Ricochet firing is most generally employed in the attack of fortresses in order to enfilade or rake the faces of works, whose fire might be directed upon the ground on which the approaches are to be made: for that purpose a battery of the besiegers is placed with its front perpendicular to the prolonged direction of each rampart or parapet, and three or more guns are laid either horizontally or with slight elevations or depressions, according to the position of the battery, so that their shot may pass a little above the crest of the parapet which covers the line to be enfiladed. The same mode of firing is also occasionally employed by the besieged against the batteries of the enemy. In either case the intention is to dismount the artillery by causing the shot or shells to strike it obliquely behind the parapet or epaulement, or to destroy the traverses which cover it. It is also used to compel the troops to abandon the parapets, or to destroy the palisades of the covered-way or ditches, so as to facilitate the entrance into a work when an assault is to be made by main force.

The practice of firing à-ricochet was first tried by Vauban at the sieges of Philipsburg and Mannheim, in the war of 1688; and in a letter which that engineer wrote to Louvois, he states that at the former place it had succeeded so far as to dismount six or seven pieces of cannon, and oblige the defenders to abandon a long branch of a hornwork and a face of one of the bastions in front of the ground on which the chief attack took place. The success of ricochet firing appears to have been still greater at the siege of Ath, which was conducted by Vauban during the same war.

It is a remarkable circumstance that, soon after the invention of this method of firing, the changes which were made in the trace or plan of fortifications, though attended with many and great advantages, were such as to render the works more liable than those of former times to the destructive action of the ricochet. The great saliency then given to the ravelins, and the consequent acuteness of the salient angles, allow the prolongation of the faces to be easily observed by the besiegers while at a distance from the work; and thus the guns in the ricochetting batteries are enabled to enfilade the faces in their whole length with great accuracy. The faces of the bastions were also lengthened about the same time; and in fortifications constructed on the inferior polygons, or those of few sides, there is a like facility of dismounting the artillery on those faces. The latter evil ceases to exist when the works are formed on the superior polygons, because the prolongations of the faces of the bastions may then fall upon the intermediate ravelins, and thus be invisible to the enemy; but, for the damage to which the long faces of the ravelins are exposed, no other remedy can be found than in the construction of traverses or blindages on the terrepleins, or in covering the general direction of the faces by an advanced portion of the latter, about twenty yards long, on each side of the salient angle.

The French engineers divide ricochet firing into two kinds, of which one is designated *ricochet mou*, and the other *rickochet tendu* (short and long-ricochet); the former comprehending all elevations of the piece, from the greatest which the charge and the gun-carriage will permit, to that which is but little above the horizon; and the latter term being applied to all other cases, down to that in which, from the height of the battery, the gun is depressed below the horizontal plane. When the crest of the parapet which covers the rampart or the ground to be ricochetted is above the level of the battery, the coincidence of that crest with the vertex of the trajectory forms the inferior limit to the elevation of the piece; for if the shot were to pass closely over that crest with a lower elevation, it would at that place be in the ascending branch of the curve, and then the ground behind the covering parapet would not, to a considerable distance from thence, be struck. In proportion as the elevation of the piece is increased above the same limit, the vertex of the trajectory is nearer to the battery, and thus the shot is in the descending branch when it passes over the crest of the work.

When the parapet over which the shot is to pass has little elevation above the battery, it requires considerable charges to allow the vertex of the trajectory to coincide with the crest; but the charges diminish rapidly as the height of the parapet increases, or as the distance of the battery from thence diminishes: the effect of this is to produce the kind of ricochet first mentioned above, for the angle made by the descending branch with the horizontal ground being greater, the rebounds of the shot are more numerous within a given extent of ground, and between the successive grazes the curves are higher and shorter. In this case, and when the descending branch passes through the crest, the shot falls almost immediately behind the parapet, and no part of the ground to be ricochetted is free from its action: this is not always certain, when by great charges and low elevations the second kind of ricochet is used, since it may happen that the shot will pass above the objects which it should strike within the limits of the ground. In the modern system of fortification the greatest length of the faces of works which are liable to the ricochet is about 100 yards; therefore when there are no traverses on the terreplein, and it is merely required to strike an object somewhere between the crest of the covering parapet (supposed to be about 8 feet high) and the further extremity of any such face, the descending branch of the trajectory will make with the horizon an angle of about one degree, and the charge and elevation of the gun should be determined so that this condition may be fulfilled. From shot so fired a traverse near the covering parapet would entirely protect the ground, since the projectile would lodge in it, and do no harm to the defenders; and in order that the fire of shot may do execution, whether made in that manner or with an increased elevation of the piece so as to produce ricochets, it is necessary previously to destroy the traverse by shells fired as above described. For such a purpose General Millar's 8-inch howitzers will probably be found to be the most serviceable; and if the large shot subsequently fired à-ricochet to dismount the artillery should not succeed in clearing an enemy's work of the troops who defend the parapet, spherical case shot fired from 24-pounder guns might be advantageously employed. One gun in a ricochet battery should be exactly in the prolongation of the crest of the parapet on the face to be enfiladed, in order that its shot may graze, with the long ricochet, the interior slope of such parapet.

Experiments in ricochet firing were carried on at Woolwich, in the months of June and October, 1821, when a work 100 yards long, and resembling the face of a bastion or ravelin, was enfiladed in that manner with iron and brass ordnance of different natures; the covering face was eight feet high, and its crest was nearly on a level with the axes of the guns in the battery. The results were, that with a range equal to 400 yards, and a charge of powder equal to $\frac{1}{16}$ of the weight of the shot, about two-thirds of the number of rounds took effect; at 600 yards, with charges varying from [illegible] to [illegible] of the weight, from one-third to one-half took effect; and at 800 yards, with charges from [illegible] to [illegible], between one-third and two-thirds took effect. It was concluded therefore that ricochet batteries ought, if possible, to be at a distance varying from 500 to 600 yards from the nearest part of the line of rampart to be enfiladed; for beyond the latter distance the effect of the fire is uncertain. The long ricochet, with high charges and small elevations or depressions of the guns, may, however, be advantageously employed in firing from the ramparts of a fortress on the ground in front, or against extensive lines of works when the battery is at a much greater distance.

It appears from the experiments above-mentioned that the best elevations of ordnance for enfilading a work à-ricochet with shot or shells is that in which the axis of the piece is directed at an angle varying from 6° to 9° above a line drawn from the chamber of the gun or howitzer to the crest of the parapet over which the projectile is to pass. It is stated that of 170 shells filled with powder which were fired, 58 took effect, but only 33 burst in the work. Before the traverses were constructed several guns on the work were struck and rendered useless; but afterwards, though the traverses were much injured, none of the guns protected by them were disabled.

When employed against troops in the field, ricochet firing is found to be of essential service; for the shot making on the ground eight or ten grazes, it cannot fail at some of these to take effect. In 1757, the King of Prussia had several six-inch mortars mounted on travelling carriages; and from these he caused shells to be thrown à-ricochet, in an oblique direction, against the enemy's line, which it immediately put in great disorder.

Ricochet firing, when first employed in sieges, from the defenders not being prepared with means to diminish its destructive effects, produced immediately a strong impression of its power; and the opinion of its superiority to the direct mode of firing has continued to prevail from the time of Vauban to the present day, though the service of artillery is now so precise, that when the guns in an enemy's work can be seen, they can be as readily dismounted by the latter mode as by the ricochet. It ought also to be remembered that before the latter can be usefully employed, the parapets, traverses, or blindages which cover the artillery of a fortress must be ruined by other means; and it may reasonably be concluded that the rapid reduction, or the most protracted defence of a place, will always be owing to a judicious combination of the different modes in which, according to the circumstances, artillery can be used during the siege. [SIEGE.]

Though it has been stated that with Mr. Whitworth's rifle gun some very good ricochet practice has been made, it is very doubtful whether rifle cannon can be employed for this purpose, as from the rotation of the shot it is deflected immensely on striking the ground. In fact, this is one of the disadvantages of rifle guns.

RIFLE, or RIFLED, a term applied to muskets or pieces of ordnance when their bores are furrowed with spiral grooves. It is probably derived from an Anglo-Saxon word signifying to *rive* or *tear;* the grooves or channels being formed by a machine which scrapes away the substance of the barrel interiorly in parallel and spiral directions.

It is not precisely known at what time rifled barrels were first employed in warfare, but P. Daniel states ('Hist. de la Milice Française,' liv. vi.) that the carabiniers of the French cavalry were furnished with such arms; he also observes that they had been invented long before the time at which he wrote, and that he had seen them used before that class of troops was formed into a regiment. This circumstance took place in 1692, and we may therefore conclude that rifled arms were known on the continent about the middle of the 17th century. The historian describes the *carabines rayées*, as he calls them, as being grooved in a circular manner along the whole of the barrel; and he asserts that the range of the balls fired from them was very considerable. Rifled arms do not appear to have been introduced in the British service till the time of the American Revolutionary war.

It is sometimes asserted that grooved barrels were introduced by Gaspard Zollner of Vienna, in 1498, but these grooves were parallel to the axis of the piece, and were only intended to take off the foulness of the discharge and assist in loading. It may accidentally have been discovered that by making the grooves spiral, greater accuracy was obtained. It is also asserted that elongated projectiles were fired from rifles many years ago, as, for instance, it is stated that Hamilton of Bothwell-haugh shot the regent Murray with a cylindro-conical bullet. But it is difficult to determine this with any certainty. Under the head of GUNNERY the effect of the rotation of a projectile has been investigated, and it is there shown that, except when the axis of rotation is coincident with the line of flight, or speaking more correctly as the trajectory is a curve, except when the axis is tangential to the trajectory, the effect of rotation on a projectile passing through the air is to deflect it more or less from the direction in which it is projected. This effect is due to the fact of the surface of the projectile being more or less rough, and to the atmosphere being more condensed in front than behind it from its high velocity. But it is not the *direct* result, if we may so term it, of the greater friction in front than behind the centre of gravity, as is often erroneously stated, and this the experiments of Professor Magnus of Berlin have shown. Indeed, the direct effect of this friction would be to deflect the ball in exactly the opposite direction to what in practice is found to be the case. A ball, for instance, rotating on a vertical axis, when the anterior surface is moving from right to left, would, the air being more condensed before than behind, meet with a great resistance to rotation from the friction of the air in front, which would not be counter-balanced by an equal resistance in the opposite direction behind; but as the rotation in front is from right to left, this resistance would in effect tend to deflect the centre of gravity from left to right. Now in practice it is found that a rotation from right to left deflects the ball to the left, so that it is evident that some other force must be called into action which overcomes this direct effect of friction. Now one half of the ball, supposing it to be cut into two hemispheres by the plane of the trajectory, is rotating with, and the other half in a contrary direction to, its motion of translation, and the surface of the ball not being perfectly smooth, the air is assisted in rushing past the former hemisphere, while it is retarded in passing the latter, and becomes more condensed. The experiments of Professor Magnus, in which a current of air was thrown on a rotating cylinder, clearly showed by an arrangement of vanes, which it is unnecessary to explain here, that the rotating cylinder caused a current in the air in contact with it, in the direction of the rotation which, where it met the current thrown on it by the blowing fan, produced a greater pressure of the air on that portion of the cylinder: that is, where the latter current was moving in an opposite direction to the former. Returning again to the ball rotating from right to left, this will account for a greater pressure on the right side than on the left, tending to deflect the ball to the left, and this cause of deflection is found to overcome the tendency before spoken of to deflect it to the right. The *figs.* 1 and 2 on the accompanying diagram may make this clearer. The motion of rotation is in both cases indicated by the arrow on the circumference, the motion of translation by the arrow in the circle. *Fig.* 1 gives the resultant direction from friction only; *fig.* 2 shows the condensation of air from the two currents meeting. It is most probable that the velocity of rotation is not so rapidly destroyed as the velocity of translation, which will account for the lateral deviation of a rotating projectile being found in practice to increase in a much greater ratio than the distance:—the trajectory being in fact a curve of double curvature. This was very well shown by Robins, to whom the first investigation, and indeed the principal portion of our present knowledge of this subject is due, in his experiment before the Royal Society in 1746, in the gardens of the Charter House (see page 165, Boxer's 'Treatise on Artillery'), where he fired a bullet from a bent gun-barrel through two paper screens, and on to a wall. The bullet followed the direction of the bent portion of the barrel in passing through the first screen and partially through the second, but the place where it struck the wall was on the other side of the line of direction of the straight portion of the barrel. The end of the barrel being bent to the left, the bullet in rolling against it in its passage out had received a rotatory movement, its anterior hemisphere moving from left to right, which for the reasons before stated caused it to deflect to the right, and the velocity of translation diminishing more rapidly than the velocity of rotation, this deflection was in a curve. This curve being combined with the curve caused by the action of gravity gives a curve of double curvature.

Fig. 1.

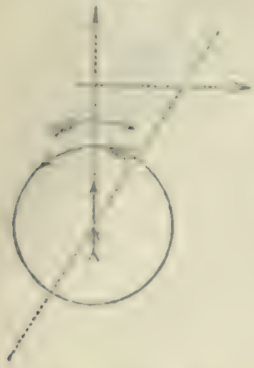
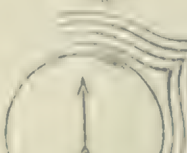


Fig. 2.



Let us now apply these considerations to the action of an ordinary smooth bore gun, whether musket or piece of ordnance.

In order that the shot may be forced down the bore of the gun it must be slightly smaller than the bore, the difference in diameter of the two being called windage. Windage, besides allowing a great escape and waste of gas, causes deflection in two ways, first the ball resting on the bottom of the bore of the gun is forced down by the gas rushing over it at the same time that it is forced along, and bounding up again from its elasticity it is carried along the bore, rebounding from side to side, and eventually leaves it, not in the direction of the axis, but in some other direction depending on its last impact. Secondly, from this last impact it will carry away a certain rotatory movement, which for the reasons before given will cause it to deflect.

The eccentricity of the projectile is another cause of deflection in smooth-bored guns. For the reasons given in the article GUNNERY, this eccentricity will in the bore of the gun cause rotation, and, as there stated, the effects of this rotation will be the same in nature as those due to the roughness of surface before considered, while they will be greatly augmented. Roughness of surface and imperfection of form are the last causes of deflection, and they are the means by which rotation causes deflection.

Windage may be lessened by increasing the size of the shot and various other means, but practically it cannot be destroyed, except in breech-loading guns.

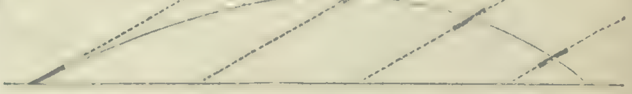
Eccentricity, arising from the material of the projectile not being homogeneous, is in musket bullets wholly overcome by making the bullets by compression, instead of casting them, as in cooling a void is often left in the interior; and may to a great extent be avoided by care in the projectiles used in larger ordnance.

Bullets can never be made perfectly smooth. Rotation can never be avoided in smooth-bored guns. It can to a certain extent be taken under control by making the shot purposely eccentric [GUNNERY], but this is a very uncertain process. We come then to the rifle, in which we have the power of impressing a certain fixed rotation on the bullet; a rotation always bearing in velocity a fixed relation to the initial velocity of the bullet. And in direction, a rotation which being round an axis that during the first portion of the trajectory, at all events, is tangential to it, causes the resistance of the air to be equally distributed round the pole of rotation, and brings any imperfections of surface rapidly round from one side to the other of the axis, and corrects any deflection arising from them at each half revolution of the bullet. Thus we obtain accuracy in its flight.

According to the laws of rotatory bodies, the tendency is for the axis of rotation always to remain parallel to its original direction. Hence we have the power of using elongated bullets from rifles; bullets, for instance, of a cylindro-conical form, termed *pickets*. These being made to rotate on their longer axis, constantly present their points to the resistance of the atmosphere, and at the same time that they present an area of resistance of the same size as a spherical bullet of the same diameter, they possess, supposing them to start with the same initial velocity, a much greater momentum to overcome this resistance. Therefore, the retardation being less [GUNNERY], we obtain a greatly increased range. A cylindro-conical picket cannot be fired from an ordinary smooth-bored gun, because, assuming a rotation almost immediately on leaving the muzzle round some of the shorter axes, all advantage is lost.

The tendency of all rotating bodies to rotate round the shortest axis of greatest moments is an important consideration in the construction of rifle pickets. If the cylinder be very long and solid, the tendency is for the bullet to *upset* during its flight. The hollow at the base of most rifle pickets is therefore of great assistance in retaining the impressed rotation. There are two other points connected with the rotation of the picket, which it may be as well to notice before proceeding to the description of the rifle itself.

Fig. 3.



The tendency of the axis of rotation to remain parallel to its original direction is the cause of a peculiar deviation, termed by the French *derivation*. It was pointed out by Robins, that when the elevation of the piece is high, and the trajectory greatly curved, the axis of the bullet, or of rotation, does not remain tangential to the trajectory, but very soon begins to make an angle with it, which angle continues to increase to the end of the range (*fig.* 3); the consequence is, that there is an inequality in the resistance of the air on different sides of the axis; the bullet or picket presents an increased rotating surface to the condensed air, that is, there is a greater resistance from friction on one side (below) the axis of rotation than on the other; the effect of this resistance will, for the reason before given, cause the bullet to deflect or derivate. But this resistance is almost wholly below, and of the same nature as that shown, *fig.* 1, as acting on the anterior hemisphere of the spherical bullet, whilst little or none of the opposing resistance of condensation of air from the meeting of two currents can be called into play (or rather, it will be in a position where it can have little effect) consequently, the bullet or picket, supposing it to have a right-handed rotation from above downwards, viewing it from behind the piece, will have a derivation to the right. The path of the centre of gravity of the shot will be a line of double curvature, but the axis of rotation will remain constantly parallel to its original direction. Robins proposed that the bullets should be formed like eggs, the longer axis being placed in the direction of the axis of the piece, and the larger end to the front, in order that, the centre of gravity being forward, the greater resistance of the air acting behind might throw the point down, and constantly keep the axis tangential to the trajectory. More recently, *canelures*, grooves cut round the base of a cylindro-conical bullet (see *fig.* 6), have been proposed by M. Tamissier, and employed with the same object. But a slight consideration will show that the action of this increased resistance behind the centre of gravity is not simply a force tending to produce angular motion in the axis of the bullet in the plane of the trajectory round an axis perpendicular to it, but is of the nature of the action arising from the friction of the rotating bullet or picket, when its axis is inclined to the trajectory, and which we have just been discussing. But it must be remembered, that we were then assuming either that the resistance of the atmosphere was equal on both sides of the centre of gravity, or that any slight inequality there might be was not sufficient to overcome the effect of rotation in keeping the axis parallel to its original direction; whereas now, from the object of the canelures, in order that they may be effective, we must assume that the increased resistance behind the centre of gravity is sufficiently great to give angular motion to the axis of rotation. For the same reason, then, that the bullet or picket would in the former case deflect to the right, supposing it to have a right-handed twist, in this case the portion behind the centre of gravity would deflect more, proportionately to the greater resistance on it, than the portion in front; that is, the axis or head of the bullet must turn to the *left*, making an angle with the plane of the trajectory. In this position the combined forces will tend to depress the head, and so on, if we consider it in its successive positions, with the forces acting on it, we shall see that the effect of the increased resistance behind the centre of gravity will be to make the bullet assume a second motion of rotation—one motion of rotation, the original one, being round the longer axis, while the second will be round an axis making an angle with this, and directed to the left of the tangent of the trajectory at every moment;—though the deflection from this oblique surface would be to the left, and counteracting the deflection it was intended to counteract, yet the *wabbling* motion the bullet must assume would be very destructive to accuracy and penetration. When from the form of the bullet the resistance is greater in front of the centre of gravity, and sufficient to give angular motion to the axis of rotation, the second axis of rotation will be directed to the *right* of the tangent of the trajectory, and there will be increased deflection to the right.

These effects may be proved experimentally with the gyroscope. It is, therefore, better, as the derivation when the axis of rotation remains parallel to its original direction is pretty constant for the same distances, to allow for it when laying the gun, than to try and correct it by the form of the shot.

Another curious effect arising from the action of rotation, tending to keep the axis of rotation parallel to its original direction, is, that at certain low elevations the range of the elongated projectile is absolutely greater in the atmosphere than it would be in vacuo. This is evidently a point of great importance practically. It is thus explained by Sir W. Armstrong: "In a vacuum, the trajectory would be the same, whether the projectile were elongated or spherical, so long as the angle of elevation and the initial velocity were constant; but the presence of a resisting atmosphere makes this remarkable difference, that while it greatly shortens the range of the round shot, it actually prolongs that of the elongated projectile, provided the angle of elevation do not exceed a certain limit, which in my experiments I have found to be about 6°. This appears at first very paradoxical, but it may be easily explained. The elongated shot, if properly formed, and having a sufficient rotation, retains the same inclination to the horizontal plane throughout its flight, and consequently acquires a continually increasing obliquity to the curve of its flight. Now the effect of this obliquity is, that the projectile is in a measure sustained upon the air, just as a kite is supported by the current of air meeting the inclined surface, and the result is, that its descent is retarded so that it has time to reach to a greater distance."

The following example, to prove the truth of this statement, is taken from 'Elementary Lectures on Artillery, R. M. Academy,' by Major Owen, R.A., and Captain Dames, R.A., from which also some of the figures are taken: "The initial velocity of the projectile from Sir W. Armstrong's 12-pr. gun is said to be 1080 feet per second; what would be its range in vacuo when fired at 2° of elevation?

$$R = \frac{v^2 \times \sin 2a}{g} = \frac{\overline{1080}|^2 \times \sin 4^\circ}{32} = \frac{1166400 \times \cdot 069}{32}$$
$$= 2515 \text{ ft. or } 838 \text{ yds.}$$

If 1100 be taken as the velocity, 880 yards would be the range. From the table of ranges given in the 'Manual of Artillery Exercises,' 980 yards is the range obtained with this gun at an angle of 2° of elevation. The range of the projectile in the air exceeds therefore that in vacuo by about 140 yards, if the initial velocity is 1080 feet a second, and by 100 yards should the velocity be 1100 feet a second." A 32-pr. shot fired at an angle of 2° with a velocity of 1600 feet per second, ranges less than ⅓ of the distance it would range in vacuo.

The interior of a rifle barrel is a cylinder, with a certain number of grooves cut in it; these grooves are parallel to one another, but make an angle with the axis of the cylinder or barrel—that is, they are disposed spirally round it. The bullet fitting these, when forced through the barrel by the action of the powder, acquires a motion of rotation round the axis of the piece in addition to the motion of translation, and this motion it of course retains after leaving the piece. The rifle barrel is in fact a female screw, and the action is the same as that of a nut through which a screw is driven by pressure.

The elements of a rifle may be considered to be a cylinder, grooves, bullet, and method of making the bullet fit the grooves or take the rifling. No rules for these various points have at present, at all events, been established; though perhaps Mr. Whitworth in his experiments has done more than anyone else to establish some of them on a scientific basis. But at present the diameter of the cylinder, that is, the bore; the number, and depth, and inclination of the grooves; the form and weight of the bullet, and the method of making it take the rifling—vary with every nation, and indeed with almost every gunmaker. We can therefore merely attempt to give some description of one or two of the most general forms of rifle. Before doing so, however, it may be as well to consider what are the points to be borne in mind, or what are the conditions of the problem of constructing a perfect rifle. This will assist us in coming to a conclusion as to what rifle combines the before-mentioned elements in the best proportions.

1st. The action of a rifle being the same as that of a nut on a screw driven through it, the action of the powder on a bullet in a rifle barrel must be the same as that of a pressure moving a body up an inclined plane, the direction of the pressure being parallel to the base. The greater the inclination of the plane, the less the velocity in the direction of the pressure generated in the body in its passage over a given space in the same direction, because of the greater inclination of the plane, and also because of its thereby increased friction.

In the rifle, therefore, the greater the inclination[*] of the grooves, the less will be the initial velocity due to a given charge. Hence the inclination of the grooves should be the least that will effect the purpose; that is, that will give the bullet sufficient rotation round its axis to retain it parallel to its original direction during its flight. This inclination, as given in 'Straith's Artillery,' by Cook and Hyde, is—

Enfield	1° 19′ 11″
Jacob's	2° 30′ 0″
Whitworth's	4° 3′ 0″

With respect to the form to be given to the grooves in section, and their number, it is evident that the main consideration on which they depend is the manner in which the projectile takes its rifling. If it is by the expansion produced by the explosion, it is evident that they should be wide and shallow, rounded and not angular, while the groove or furrow on one side is opposite the projection or land on the other side. The Enfield rifle, described further on, with its three wide, shallow, rounded grooves, fulfils these conditions. If on the other hand the projectile takes its rifling by being forced into a narrower bore, as in the breech-loaders, it is evident that the cutting portions, the lands, should be narrow, the grooves not very deep, not deeper than will just suffice to give a sufficient hold, with sharp angles and square sides at least on one side. The Armstrong gun [RIFLED ORDNANCE], with its numerous narrow lands and furrows, is made in this way.

If the projectile is formed to fit the grooves for convenience in loading, they and the projections on the projectile to fit them should be made prominent and well marked, as in the two-grooved rifled Jacob's or Whitworth's. This last mentioned form, however, is also well adapted for an expanding ball, and while it gives a perfect hold on the projectile reduces friction to a minimum.

2nd. The picket should be as long in proportion to its diameter as possible; for, *cæteris paribus*, the longer and thinner the projectile is, the greater will be its range and accuracy. But at the same time it must be remembered that, first, especially for military rifles, there are great objections to a very small bore and attenuated picket: the former being difficult to clean, the latter liable to injury, and requiring a long fragile cartridge. Secondly, the inclination of the grooves is necessarily increased, in order to give the picket sufficient rotation; which, besides being objectionable for the reasons before given, renders the bullet liable to strip, especially with the soft metal required in expanding bullets. Thirdly, the bore may be so diminished as to prevent the power of giving the picket sufficient initial velocity; that is to say, that, given the calibre, there is a limit beyond which it is detrimental to increase the length and consequent weight of the projectile, on account of the mechanical distribution of the charge.

3rd. There are certain mechanical considerations: among which are a barrel of sufficient weight, perfectly true bore, with accurately parallel grooves brought to a high state of smoothness; and, when the rifling is taken by an expanding bullet, the distribution and depth of the grooves such as will allow of their being perfectly filled. Three wide shallow grooves appear the best, as in the Enfield rifle. Rifles with *gaining twists*, that is, a spiral increasing in inclination from breech to muzzle, have been tried. In fact the Lancaster rifles, with which the Royal Engineers are armed, are of this description; these have made good practice, but it may be only from superior manufacture, for it is evident that there is nothing gained, but, on the other hand, when the projectile is long, there is a constant alteration of form, causing increased resistance. These various points require a long series of carefully conducted experiments to arrive at any absolute rules.

Commencing with the greatest weight of bullet, on account of recoil, that it is possible for a man to fire from his shoulder, and investigating how far the greatest advantage in each direction may be obtained, compatibly with the conflicting considerations, is the only manner in which a perfect rifle can be formed. We believe that this is the manner in which Mr. Whitworth arrived at his proportions, and his is certainly the most perfect weapon yet produced.

The first form of rifle employed in the British service was a seven-groove rifle. The method of loading was this: after pouring in the requisite charge, a greased patch (a circular piece of cotton, about twice the diameter of bore) was placed on the muzzle; a spherical bullet, slightly larger than the bore of the gun, was then placed on it and forced down with an iron ramrod and wooden mallet. Thus the portion of the bullet in contact with the bore became indented, and received its rifling; it was, however, a long and tedious process, not well adapted for military purposes. It was superseded by the two-grooved rifle and belted ball; the grooves were wide and deep, and the bullet, which was sewn into a thin piece of calico, had a projecting zone fitting them. This form was easier to load, and gave pretty good practice up to 300 yards, but it had the disadvantage of windage, and after a time fouled.

Robins had pointed out the advantages of a breech-loading rifle, in giving ease in loading:—"As both these methods of charging at the mouth take up a good deal of time, the rifled barrels which have been made in England (for I remember not to have seen it in any foreign piece) are contrived to be charged at the breech, where the piece is for this purpose made larger than in any other part; and the powder and bullet are put in through the side of the barrel by an opening, which, when the piece is loaded, is filled up by a screw. By this means, when the piece is fired, the bullet is forced through the rifles, and acquires the same spiral motion as in the former kind of pieces. And perhaps somewhat of this kind, though not in the manner now practised, would be, of all others, the most perfect method for the construction of these barrels."

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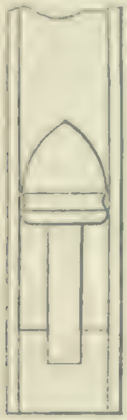
[*] The inclination of the grooves, commonly called the twist, is generally given as one turn in so many feet. This of course gives no information directly as to the proportionate inclination of the grooves in two rifles of different calibre. The correct estimate of this, is the angle of inclination of the line, showing the groove on the *developed* surface of the bore of the piece, that is, by comparing the lengths in which one turn is effected with the circumferences of the bores. This may easily be done, when we know the calibres or bores, by laying off on a line the length in which one turn or twist is completed, then laying off at right angles to this the circumference of the bore. Completing the rectangle gives the developed surface, of which the diagonal is the groove, and the angle it makes with the side of the rectangle, the angle of inclination.

This process has been carried out very successfully in the Prussian needle-gun, and various other breech-loading muskets, and in the Armstrong gun. [RIFLED ORDNANCE.] Though space will not permit of our describing the needle-gun, we may mention that there is no nipple and cap used, but the detonating powder being contained in a wooden sabot at the base of the bullet, a needle is driven forward by the lock on the trigger being pulled, and forcing through the powder in the cartridge, ignites the detonating powder at the other end. The needle being very liable to injury, a form of cartridge with the detonating composition at the back of the charge has been adopted successfully. Breech-loaders, besides increasing the rapidity of fire, enable the soldier to load without exposing himself whilst doing so, which is sometimes a great object, as, for instance, in a square.

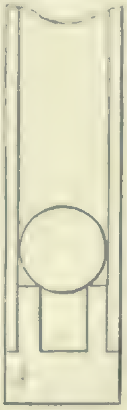
To return to muzzle-loaders. In 1827, M. Delvigne, a French officer, proposed to increase the facility of loading by giving the rifle a chamber, as *fig.* 4; the bullet being smaller than the bore is easily loaded, and when on the chamber a few smart blows with the ramrod expands it into the grooves. It did not, however, succeed well on service, for powder lodged on the shoulders of the chamber and the rifle fouled. In 1842, Colonel Thouvenin, also a French officer, invented the "carabine-a-tige," see *fig.* 5. The action is the same as with the Delvigne chamber, and needs no explanation. It answered better, but there were many disadvantages. The bullet in both cases is knocked out of shape. The tige, or steel stem, is liable to injury, and from its position takes up much space, elongating the charge and placing it at a mechanical disadvantage in its ignition. M. Delvigne then proposed the elongated bullet, as shown in *fig.* 5, which was a great improvement, and it was introduced into the French service with the carabine-a-tige.

Fig. 4.



Section.

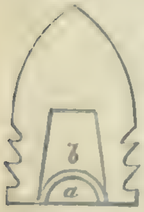
Fig. 5.



Section.

M. Minié then proposed an expanding bullet, of the form shown in *fig.* 6, with an iron cup or plug *a*, in the hollow base *b*. This remedied all the disadvantages of the carabine-a-tige. The bullet can be easily rammed down, and the iron cup having a less specific gravity than the lead is driven forward by the explosion and assists in expanding the bullet. It is but justice to Captain Norton to state that he proposed an expanding bullet on the same principle many years before. It is, however, not absolutely necessary to have a hollow base and plug in order to make the bullet expand. A hollow base alone, or indeed a solid cylinder, if long enough, will expand, though not quite so much. The powder acting like a blow drives the base forward before the inertia of the fore part is overcome, and expands it at the shoulder.

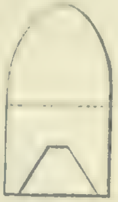
Fig. 6.



Section.

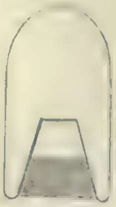
A rifle on the Minié principle was adopted into the English service in 1851. In 1852 Lord Hardinge appointed a committee to investigate the question of rifled arms, and they in 1853 adopted a modification of the bullet and arm proposed by Mr. Pritchett. *Fig.* 7 shows the bullet first adopted, without a plug. This bullet, having only a slight windage, was found to foul. One with a boxwood plug and greater windage was then adopted. *Figs.* 8 and 9 show the bullet; and *fig.* 10 the cartridge. The cartridges may be made with two different pieces of paper, one thicker than the other; but the best form is made of two seamless bags. Into the larger the bullet is forced base foremost to the bottom, the smaller is then pushed in on to the point of the bullet, and filled with powder, the ends pasted up, and the base round the bullet dipped into a lubricator, a mixture of tallow and bees' wax. In loading, the end of the cartridge is opened and the powder poured in, the bullet is then reversed into the muzzle; when down to the shoulder, the upper portion of the cartridge paper to where the inner case comes down to, is torn off, and the bullet pushed down with the ramrod. This is incomparably the best arm that any troops have *yet been armed with*, though it may not be the best weapon invented. It is wholly made by machinery, at least all those manufactured at the Government factory at Enfield (whence its name). This gives it the great advantage for a military weapon, besides perfection in accuracy, of having all its parts interchangeable with other arms of the same construction. The dimensions, &c., of the Enfield rifled musket are—

Fig. 7.



Section.

Fig. 8.



Section.

Fig. 9.

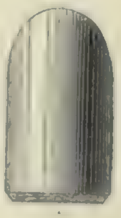
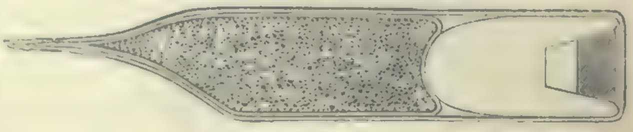


Fig. 10.



Section.

Weight, with bayonet	9 lbs. 3 oz.
Barrel, weight	4 lbs. 2 oz.
Length	3 ft. 3 in.
Bore, cylindrical diameter	·577 in.
3 grooves, uniform twist, one turn in . .	6ft. 6 in.
Inclination, therefore	1° 19′ 11″
Width of grooves	·262 in.
Depth at breech	·015 in.
„ at muzzle	·005 in.
Lock swivel—	
Mainspring, draws at half-cock	15 lbs. to 16 lbs.
Sear spring draws	7 lbs. to 8 lbs.
Pull of lock	13 lbs. to 14 lbs.
Trigger draws	7 lbs. to 8 lbs.
Charge, powder 2½ drams, F. G.	
Bullet, expanding, with box-wood plug—	
Diameter, formerly ·568 in., now reduced to .	·55 in.
Length	1·05 in.
Weight	520 grains.
Weight of 60 rounds of ammunition, with caps	5 lbs. 8 oz.
The Old Musket, with a bore of ·753, weighed .	11 lbs. 3 oz.
And the ammunition	6 lbs. 10 oz.

Good practice may be made with the Enfield up to 900 yards, to which distance it is sighted. The above are the dimensions of what is called the Long Enfield—there is a shorter arm for the Rifles, &c., the dimensions of which it is not necessary to particularise. A sword bayonet is used instead of the ordinary bayonet, but for many reasons it is more than doubtful whether the short rifle, with the accompanying awkward sword, is a more appropriate weapon. The cavalry are

Fig. 11.

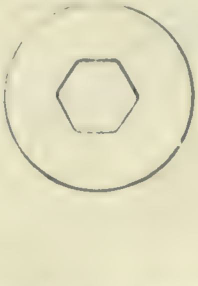


Fig. 12.

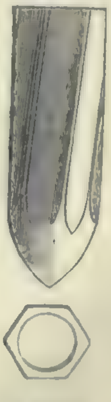


Fig. 13.

armed with a Sharp's (breech-loading) carbine, and also some, we believe, with Westley Richards's.

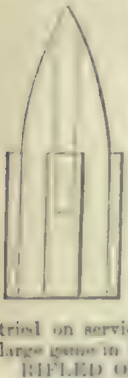
Mr. Joseph Whitworth, the eminent machine manfacturer of Manchester, has invented and patented an admirable rifle: a section of the barrel is represented in *fig.* 11; and the bullet, with a plan of base, in *fig.* 12. The bore is a hexagon in plan, or rather in cross section, with the angles rounded off, the diameter of inscribed circle being only ·45 inch. The bore is described by this hexagonal section moving from one end to the other, and rotating uniformly round the axis of the piece, so as to complete one rotation while passing along 20 inches: that is, that the grooves, if we may so term them, make one turn in 20 inches. The pickets are either of the form shown in *fig.* 11, or as shown in *fig.* 13, that is, cylindrical, and of a rather less diameter than the inscribed circle, when they are expanding. The former have the advantage of allowing the use of a hard metal (9 parts lead, 1 part tin), and consequent great penetration. By *easing off* the *edges* that *bear* in loading, the former description of bullet is easily rammed down, whilst as the bearing is thrown on the other edges as it is being driven out, almost all windage is stopped.

A trial took place in April, 1857, between these rifles and the Enfield, at Hythe School of Musketry; the experiments have been objected to on various grounds, but it may be as well to give the results:—

Rifle.	Range in yards.	Elevation.	Figure of Merit.
		Degrees.	
Whitworth . .	500	1·15	0·37
Enfield . . .		1·32	0·24
Whitworth . .	800	2·23	1·0
Enfield . . .		2·45	4·11
Whitworth . .	1100	3·45	2·41
Enfield . . .		4·12	8·04
Whitworth . .	1400	5	4·62
Enfield . . .		6·20 to 7	No hits.
Whitworth . .	1880	6·40	11·62
Enfield . . .		..	..

The figure of merit is the mean radial distance in feet from their centre of 10 shots fired from a rest table. A Whitworth bullet, with the service charge of 2½ drachms of powder, penetrated thirty-three ½-inch planks of elm, and was only stopped by a solid balk of timber behind them. Mr. Lancaster's rifle, which has before been mentioned, has a gaining twist; the section of the bore is an ellipse; the bore is formed by this ellipse moving along the axis of the piece at the same time that it rotates round it, rotating, not uniformly, but more rapidly as it comes towards the muzzle. The rifles with which the Royal Engineers are armed, on this principle, take the same ammunition as the Enfield, and make good practice up to 1000 yards.

Fig. 14.



The last rifle we need mention is that invented by General Jacob. The form of bullet is seen in *fig.* 14. The grooves are of considerable depth, four in number, and are as wide as the lands. The diameter of the bore is the 32 gauge. The picket is solid, and has four projections to fit the grooves. The grooves make one turn in 36 inches. General Jacob made many experiments with shells from his rifles. These shells had been invented many years ago by Captain Norton, and having improved upon them, General Jacob made a most formidable weapon, exploding ammunition waggons at 1600 and 1800 yards distance. The picket is cast with a cylindrical cavity in its conical end, into the cavity is inserted a copper tube, filled with fine-grain powder, and primed at the point with a detonating composition. These shells may be very useful, though they have never yet been tried on service, but they have been found very effective against large game in India and Africa.

RIFLED ORDNANCE. In the year 1774, Captain Blair proposed the formation of rifled guns of iron, to be used as field artillery. Agreeably to the old practice, they were to be made hollow in the act of being cast, and in the same operation the grooves were to be formed. The balls were to be of lead, with knobs on them to fit the grooves, and they were to weigh not more than two pounds. About the beginning of this century, the French attempted to introduce into their service cannon shot of a cylindro-spherical form, the cylindrical part being in contact with the charge of powder, and a ring of lead surrounding the shot near its middle, so as to render this part rather greater than the bore of the gun. The circumference of the ring being scraped down by the edge of the muzzle when the shot was forced into the gun, became in close contact with the surface of the bore, and thus no windage was left. By this contrivance it was expected that most of the advantages of a rifled gun would be obtained, though no rotatory motion took place in the shot. The result of the trials was thought to be favourable with respect to the direction and range of the shot; but the labour and time required to load the gun were great, and this circumstance probably prevented the invention from being adopted.

In 1846, Major Cavalli, of the Sardinian Artillery, invented a rifled gun; and about the same time another was proposed by Baron Wahrendorff, a Swede. Both were two-grooved breech-loading pieces. In 1850 these guns were experimented with at Shoeburyness against the service 32-pounder of 56 cwt. The weight of the elongated projectile for both guns was about 64 or 65 lbs. Space does not permit of our entering into a description of them; but some remarks of Sir H. Douglas on the result of the experiments may be quoted:—"At the efficient service elevation of 5°, with charges of 8 lbs., the ranges, and also deflections, of the different projectiles were nearly equal to one another; and the like is true with charges of 10 lbs. At elevations of 10°, the ranges of the foreign guns exceeded those of the English 32-pounders, with charges of 8 lbs., by 380 yards, and with charges of 10 lbs. by 690 yards; and at elevations of 15° the excess was, with charges of 8 lbs., about 790 yards, and with charges of 10 lbs. about 1100 yards." The deviations, which were always in the direction of the rotation of the projectile, were so variable that no allowance could be made for them. The Wahrendorff gun had considerable advantages in length of range over the 32-pounder at high elevations, but the practice was then very uncertain. After four rounds, the Cavalli gun became unserviceable by the copper ring embedded in the metal of the gun at the bottom of the bore being damaged. The attempt to repair this was unsuccessful, for, on a further trial, the whole breech was blown away. The Wahrendorff gun, however, stood well.

The next rifle gun invented was that by Mr. Lancaster. It was tried at Shoeburyness in 1851. The principle was similar to that of the rifle [RIFLE]—an elliptical bore, with a gaining or increasing twist. In fact it was a two-grooved rifle, with the angles of the grooves chamfered off. The friction in the bore was so great that it was necessary to make the projectile, which was cylindro-conoidal with an elliptical section, of wrought iron. This was the first rifled cannon ever used in war, and was employed by the English in the Crimea, both on board the gun-boats and in the batteries, against Sebastopol. Though good results had been obtained in 1852 at Shoeburyness, with spheroidal projectiles from these guns, they did not succeed well on service. The trial was certainly hardly a fair one, many of the guns being light 8-inch, bored up; and these burst. Some of the heavy 8-inch Lancaster guns, however, also burst with the elongated projectile, we believe. Those who worked the guns had in many cases not been instructed in their use; and Mr. Lancaster has accounted for the shells constantly bursting in the bore by the welding of the two pieces of wrought iron with which they were made not being a perfect joint, and the explosion of the gun communicating to the interior of the shell. But it is most probable that the shell jammed in the bore, which it was very likely to do from its form and the increasing twist. Certain it is that the practice was very uncertain, and the result not satisfactory.

Under the heads of GUNNERY and RIFLE we have considered the points to be attended to in the formation of rifle arms and projectiles. These are equally applicable to ordnance. But when we come to the manufacture of very large guns, either smooth bore or rifled, we meet with a difficulty in making them sufficiently strong to resist the effect of the explosion of the charge. This difficulty arises as we increase the diameter of the bore much sooner in rifled pieces than in smooth bores, because in the former there is a greater resistance to the motion of the projectile in the bore, while at the same time the elongated projectile employed is of greater proportional weight. It has been however found very difficult to make solid shot guns—that is, when heavy charges are employed—of a greater diameter of bore than 8 inches (the 68-pounder); and in the war with Russia it was found that the 13-inch mortars, even the immensely heavy sea service ones, constantly burst after heavy firing, as at Sweaborg.

This can be easily understood when we remember that, in guns of the ordinary construction, it is useless to increase the thickness of metal beyond a certain limit, and that to produce equal initial velocities in two similar projectiles of different diameters—as, for instance, two spherical shot of 2 and 4 inches diameter—the pressure or strain on the metal of the gun increases in a ratio much higher than the ratio of the surfaces of the bores. To make the first point clear, if we take the transverse section of a gun, which is an annulus, we may consider it composed of a series of concentric rings, and the strain of the explosion a statical force, though it is of the nature of impact. That the metal of the gun is, as might be supposed, extended by the action of the powder at the moment of explosion (some portion of which extension, from want of elasticity, is permanent), may be proved experimentally; that is to say, the diameter of the annulus or transverse section is increased, but the area of the annulus must remain the same, and therefore the width of the annulus must diminish, or, which is the same thing, the circumference of the inner circle must increase in a greater ratio than the outer. Hence the greater the distance of any of the rings composing the annulus from the centre or axis of the gun, the less will it be stretched, and the less will be the strain on it, and the resistance to a pressure of any two rings will be inversely as the squares of their distances from the axis.

Now iron extends with a tensile strain, and the extension is more than proportionate to the strain; that is, the resistance to extension is only at first nearly proportionate to the extension. It is found, by experiment, that for wood and wrought-iron the resistance to extension in each fibre is at first nearly proportional to the extension. Mr. Hodgkinson found that in cast-iron the resistance to extension was less than a quantity proportional to the extension by a quantity nearly proportional to the square of the extension. If w represent resistance to extension, and e the corresponding extension, $w = ae - be^2$.

It is therefore evident that at a certain thickness of metal the cohesion or tensile strength of the inner ring may be overcome, and the ring burst before the outer ring receives any strain, and therefore it is useless to increase the thickness of metal beyond the point at which the force exerted on the surface of the bore is sufficient to rupture it before the strain acts to any extent on the exterior. With respect to the second point, taking two spherical bullets of 2 and 4 inches diameter, *cæteris paribus*, the pressure required to give them the same initial velocities will be as their weights, that is, as the cubes of their diameters, but the surfaces of the bores will only increase as the squares of the diameters, and therefore with larger calibres the strains on the guns will be greatly increased.

In order to obtain the requisite strength in rifled ordnance (especially in those of a large calibre), where the strain is again increased by the resistance to motion offered by the rifling, it is necessary to adopt some means of equalising the strains through the metal. Different ways of effecting this have been suggested. The object of all of them is to give a certain *initial* tension to the outer rings—the exterior having the greatest, and the tensions decreasing and resulting in compression in the interior. The rings can be shrunk on to an interior cylinder or core, that is, put on hot and then cooled, or they may be put on by hydraulic pressure, or the core or tube may be bound round with wire, gradually increasing the strain of each layer. Captain Blakely, R.A., who appears to have investigated the subject fully, made a gun in this last manner, which stood some most severe trials at Shoeburyness, in 1856 and 1857. The ancient built-up guns, such as Mons Meg, were often made with longitudinal bars, kept together with rings shrunk on. This process was evidently adopted on account of the imperfect state of manufacturing power, as there could be no use in not having the interior a homogeneous cylinder. A huge mortar of 36 inches diameter was, however, made in this way a few years ago by Mr. Mallet, and failed.

In 1854 Sir W. Armstrong brought forward a breech-loading rifle-gun, his plan was accepted, and a gun of small calibre having been made according to it, was tried at Shoeburyness. With some modifications this description of gun has been adopted in the British service, and found very efficient in the late China war. In fact it is the most perfect gun yet adopted in any artillery. The following description of the original gun tried at Shoeburyness, and at Sir W. Armstrong's private factory at Newcastle, is taken from the minutes of 'Proceedings of the Royal Artillery Institution,' given in the 'Elementary Lectures on Artillery for the Royal Military Academy,' by Major Owen, R.A., and Captain Dames, R.A.; from which also, and a paper on the 'Construction of Artillery,' printed by the Institution of Civil Engineers, the description and drawings of gun, shell, &c, are taken:—

"A core or internal lining was formed of cast-steel, to which the requisite strength was given by encircling it with twisted cylinders of wrought-iron made in a similar manner to gun barrels, and tightly contracted upon the steel core by the usual process of cooling after previous expansion by heat; the parts are then in a state of initial tension, which is necessary to bring their entire strength into operation. The arrangement for loading at the breech consists of a powerful screw having a hole through the centre in the prolonged axis of the bore, through which hole the bullet and charge are delivered into the gun. A "breech-piece" with a mitred face fitting a similar face at the end of the bore, is dropped into a recess, and by the action of the screw pressed tightly into its seat, so as to effectually close the bore. The fitting surfaces which close the bore were at first made of unhardened steel: this failed; hardened steel was next used, but this yielded to the action of the powder more rapidly than before; copper was then tried, and no further difficulty was experienced. The breech-piece contains the vent. The bore of the gun was 1¾ inches in diameter, and contained eight spiral grooves, having an inclination of one turn in 12 feet; these grooves terminated at a distance of 16 inches from the breech, and the bore then gradually expands in a length of 3 inches from 1¾ inch to 1⅞ inch in diameter." The gun weighed about 5 cwt.

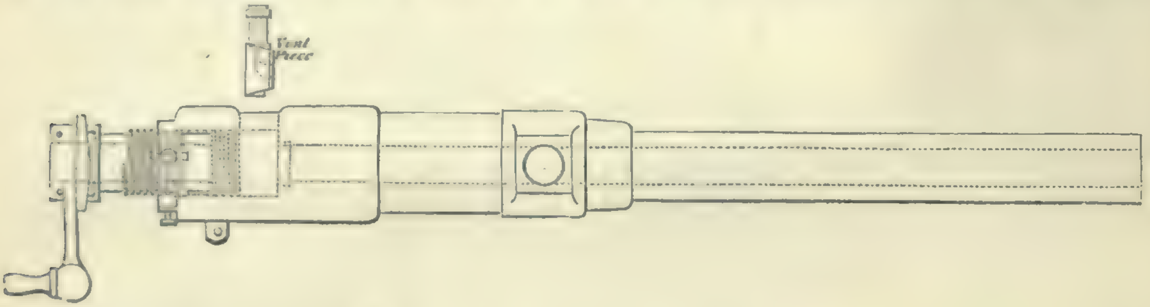


Fig. 1.—Armstrong Gun, scale ¾ inch to 1 foot ($\frac{1}{16}$).

The projectile, which is cylindro-conoidal in form, was 6½ inches long, and weighed 5 lbs.; it was of cast-iron coated with lead, and was hollow, so as to be used either as shot or shell. It was slightly larger in diameter than the bore of the gun, and being inserted at the breech took its rifling by being forced through the grooved bore.

The charge was one-eighth weight of shot. The following results of experiments are given in the 'Lectures' before mentioned:—Fourteen projectiles were fired at a butt of wood 5 feet wide and 7½ high from a distance of 1500 yards. Six shots were fired as trial shots to obtain the correct elevation. The remaining eight hit the butt without grazing, the elevation of the gun being 4° 26′, and the mean deflection from the centre line on the butt was only 11½ inches. The experiments with shells fired at two targets, placed 30 feet apart, covering one another, were equally remarkable—nearly all the shells passing through the first target and bursting before reaching the second.

This being a small gun was of course easy of manufacture, but Sir W. Armstrong has been equally successful in making 12, 25, 32, and 40 pounders; and experiments are now being made with much heavier guns, 70, 80, and 100 pounders.

The 12 pounder is the gun adopted for the field batteries and horse artillery. Those used in China have weighed 6 cwt., with a charge of 1 lb. 6 oz. It is probable that in future the 8 cwt. gun, with a charge of 1 lb. 8 oz., will be adopted. The guns are now made wholly of wrought iron, and in order to avoid the difficulty of forging very large masses they are made in pieces, tubes from 2 feet to 5 feet long, which are then welded together. The tubes are formed by winding long bars of heated iron round a roller, the coil is then brought to a welding heat and hammered together; the edges of the coils or tubes having been bevelled off, the tubes are welded together. The manufacture is very complicated. The finished gun is shown in *fig.* 1. The grooves are very narrow and shallow. The driving sides, that is to say, the sides the projectile bears on in passing out of the gun, are cut square, or at least radial, the other edges are rounded off.

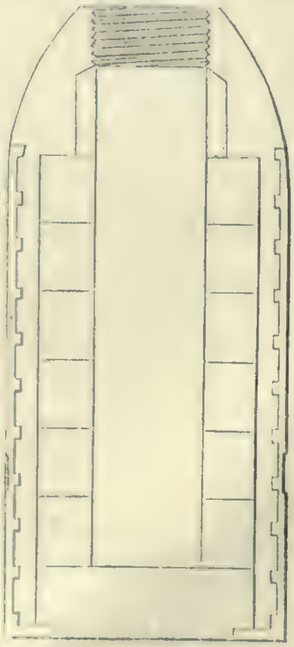


Fig. 2.—Armstrong Shell, scale ½.

The width of the lands and grooves being the same, they vary in number according to the calibre of the piece,—the 12 pounder has

34, the larger guns have more, -they make about half a turn in the length of the piece, and the charge seems to be about ⅛th the weight of the projectile. The construction of the projectile, which is shown in *fig.* 2, has been thus described by Sir W. Armstrong. "The projectile consists of a very thin cast-iron shell, the interior of which is composed of forty-two segment-shaped pieces of cast iron built up in layers around a cylindrical cavity in the centre, which contains the bursting charge and the concussion arrangement. The exterior of the shell is thinly coated with lead, which is applied by placing the shell in a mould and pouring melted lead round it. The lead is allowed to percolate among the segments, so as to fill up the interstices, the central cavity being kept open by the insertion of a steel core. In this state the projectile is so compact that it might be fired through 9 feet of hard timber without injury, while its resistance to a bursting force is so small that less than one ounce of powder is sufficient to break it in pieces." It is a great advantage for service to have a projectile of this description, which can be used as shot, shell, shrapnell, or case. The simplicity of ammunition is perfect when one form serves all the purposes that can be required, for it is only necessary in using it as shot not to put in a fuze. The shell can, as will be seen, be made, according to the fuze, either a *time* shell or a *concussion* shell. By adjusting the fuze so as to burst the shell just short of the object, we have a shrapnell of the most perfect description, for a small bursting charge will liberate the numerous segments of which the shell is formed; while, by adjusting the fuze so as to burst the shell at the muzzle, we may use it as case. Sir W. Armstrong stated in a speech he made at Newcastle, that the shell burst into 49 regular pieces and about 100 irregular pieces. And also that for breaching purposes, firing at buildings and ships, a different construction of shell was adopted, the object being to introduce the largest possible charge of powder. The shell of the Armstrong 32-pounder contains about twice as much powder as that of the ordinary 32 pounder.

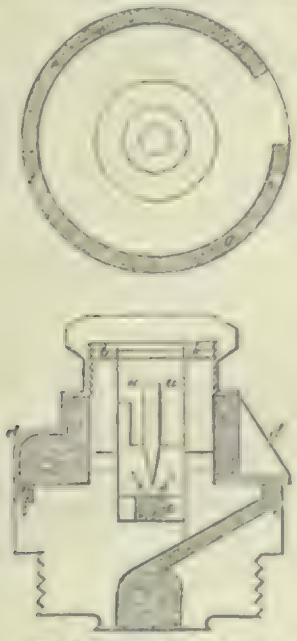


Fig. 3.—Time Fuze, full size.

a a, the hammer; *b b*, the suspending pin; *c*, the detonating composition; *d d*, the hollow collar; *e e*, the fuze composition.

The two descriptions of fuzes, *figs.* 3 and 4, are thus described by Sir W. Armstrong. "The body of the time fuze, *fig.* 3, is made of a mixture of lead and tin, cast to the required form in a mould. The fuze composition is stamped into a channel forming nearly an entire circle round the body of the fuze, and is afterwards papered and varnished on the external surface. As the shell fits accurately into the gun, there is no passage of flame by which the fuze could be ignited. The effect is therefore produced in the following manner — A small quantity of detonating composition is deposited at the bottom of the cylindrical cavity in the centre of the fuze, and above this is placed a small weight or striker terminating in a sharp point presented downwards. This striker is secured in its place by a pin, which, when the gun is fired, is broken by reason of the *vis inertiæ* of the striker. The detonator is then instantly pierced by the point and is thus fired. The flame thus produced passes into an annular space formed within the revolving cover, which rests on the upper surface of the fuze composition, and from this annular space it is directed outwards through an opening, so as to impinge on and to ignite the fuze composition at any required part of the circle. The fuze thus ignited burns in both directions, but only takes effect at one extremity, where it communicates with a small quantity of powder in the centre. The fuze is surrounded by a scale paper graduated to accord with the elevation of the gun, so that when the range of a distant object is found by trial, it is only necessary to turn the igniting aperture of the cover to the point on the fuze scale corresponding with the degrees and minutes of elevation on the tangent scale.

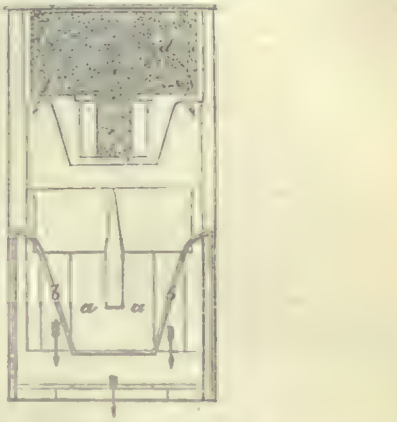


Fig. 4.—Concussion Fuze, full size.

a a, the hammer; *b b*, the suspending pin; *c*, the detonating composition; *d d*, priming chamber.

The concussion fuze (*fig.* 4.) is on nearly the same principle. "A striker with a point presented upwards is secured in a tube by a wire fastening, which is broken on the firing of the gun; the striker being thus liberated recedes through a small space, and rests on the bottom of the tube, but as soon as the shell meets with any check in its motion, the striker runs forward and presses the detonator in front, by which means the bursting charge is ignited." To show the extreme accuracy of the Armstrong shell and fuzes, we may mention an experiment which took place before the Duke of Cambridge and a number of distinguished officers. Two targets, each of 9 feet square, were placed at a distance of 1500 yards from the gun, and 7 shells were fired at them; the effect of these 7 shells was, that the targets were struck in 596 places. Similar effects were produced at 3000 yards with shells, and a target 9 feet square has been struck with shot 5 times out of 10 shots. At 600 yards an object the size of the muzzle of a gun can be struck almost every time with the shot or shell. The tabular statement below will explain the advantages of rifled ordnance at long ranges, while the short ranges at low angles of elevation will be easily understood, for the reasons given under GUNNERY and RIFLE, when we remember that the initial velocity of the Armstrong 12-pounder shot is less than 1100 feet per second, while that of the ordinary 12-pounder is about 1800 feet per second.

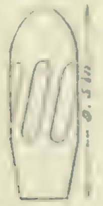
	Ranges at Elevations of						
	P. B	1°	2°	3°	4°	5°	6°
12-pounder Armstrong, weight 6 cwt., charge 1 lb. 6 oz. . .	300	600	900	1200	1500	1800	2100
12-pounder service, weight 18 cwt., charge 4 lbs. . .	300	700	1000	1200	1400	1600	1800

The first form of carriage employed for the Armstrong gun was the bracket carriage with recoil slide. The recoil slide is however abolished for field service pieces, though we believe it is intended to employ it still for garrison, siege, and naval guns. The field service carriage is now in form very similar to the old block trail carriage. The trunnions of the gun however rest in moveable trunnion holes. These trunnion holes being connected together by a band of iron, a horizontal motion can be given to them round a centre or pivot between them by means of a bar, which, passing to the rear almost as far as the elevating screw, has motion given to it by a horizontal screw passing through its end. By this means the gun carriage having been brought into the general direction of line of fire, the gun can be most accurately laid by merely turning the handle attached to this screw without further shifting of the carriage.

The following extract from Sir W. Armstrong's speech at Newcastle, will show the great labour it cost him to bring it to perfection, and its great power now as a siege-gun:—"To go back to the commencement of my experiments, I may tell you that they began upwards of four years ago, my first gun having been commenced in December, 1854, and completed early in the following spring; although this gun was constructed upon the same principle as those which I am now making, it did not in the first instance afford satisfactory results. Schemers, whose inventions merely figure upon paper, have little idea of the difficulties that are encountered by those who carry inventions into practice. For my part, I had my full share of such difficulties, and it took me nearly three years of continual application to surmount them. In the height of summer my experiments were for the most part carried on at the sea-coast, between the hours of 3 o'clock in the morning and 6; for after that time people began to move about and were apt to get in the way. At other seasons I availed myself of the wild moors belonging to my friend Mr. Beaumont, at Allenheads, and there I had a hut constructed on a mountain ridge, 2000 feet above the level of the sea. My targets were placed upon the opposite side of a deep valley, where nothing more valuable than grouse or lean sheep ran the risk of being shot; and well it was that such was the case, for I had constructed an instrument for maintaining a fire upon an object (a breach, for example) after darkness had set in, and I used to awaken the denizens of the heath by firing shells at my distant target in the middle of the night; and I may observe in passing that, when this instrument was fully perfected, I was enabled to strike a distant object on a pitch dark night with the same accuracy as in broad daylight. At the end of the three years I had succeeded in bringing to maturity both guns and projectiles. Several new guns had been made on my own responsibility, and considerable expense incurred on experiments; but all my disbursements were refunded by the Government as soon as the results were ascertained."

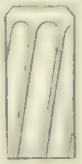
We have entered thus fully into the description of the Armstrong gun as it is the gun adopted in the service. It only remains briefly to notice the Whitworth gun and the French rifled gun. The Whitworth gun has, like the rifle [Rifle], a hexagonal bore, the angles of the hexagon being rounded off. As the projectiles are very long, the inclination of the grooves is very great. The guns with which the experiments were made in the spring of 1860, near Liverpool, were breech loaders. The following description and table of dimensions is taken from the Lectures on Artillery before quoted. "The breech is closed by a cap which screws on outside, and works in an iron hoop attached by a hinge to the side of the breech; the cap is opened back for loading, after which it is shut-to, like a door, and then screwed on to the breech by a handle for the purpose; the vent is in the centre of the cap, and therefore in line with the axis of the bore. For smaller sized guns, Mr. Whitworth uses homogeneous iron, the larger guns are made of the same material, but strengthened with wrought iron hoops fixed on by hydraulic pressure. The Whitworth projectile is hexagonal, its form corresponding to that of the bore, and it is made of cast iron accurately turned by machinery (*fig.* 5); for penetrating hard substances, as wrought iron plates, the projectile is flat headed and made of homogeneous iron (*fig.* 6). The charge is ⅙th the weight of the projectile, and it is placed in the bore in a tin cartridge which remains in until after the gun is fired, when it is removed; a wad of lubricating substance closes the front of the cartridge, and is intended to prevent the fouling of the bore."

Fig. 5.



Maj. axis, 3·1 in.
Minor, 2·8.

Fig. 6.



Whitworth Gun.

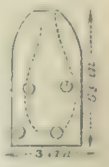
Nature of Gun.	Bore.		Length.	Weight.	Pitch of Rifling.
	Major Axis.	Minor Axis.			
			ft. in.	cwt. qrs.	1 turn in
3-pounder . .	1·6	1·48	6 0	. . .	3 ft. 4 in.
12-pounder .	3·1	2·8	7 9	8 0	5 0
80-pounder . .	5·5	5·0	9 10	80 0	8 4

With the 3-pounders the extraordinary range of 9688 yards (more than 5½ miles) was obtained at 35° of elevation. The Armstrong 32-pounder with the same elevation ranged 9130 yards.

Some of the practice with the Whitworth guns was also very accurate. It also appears to have an advantage over the Armstrong gun in range with equal elevation, and can be used either as a breech loader or as a muzzle loader, while, as explained under Rifle, ease in loading is obtained without windage. But until careful experiments have been conducted with both under the same conditions, which has not been the case hitherto, no decided opinion can be given as to the relative merits. The penetration power of the flat-headed projectile against iron plates is very great, and in fact has been more effective than any other projectile. Mr. Whitworth has found that decreasing the hinder part of the projectile has greatly increased its range.

The French 9-pounder field piece is a muzzle loading 6-grooved bronze gun weighing about 6 cwt. The calibre is about 3·36 inches, the grooves making one turn in 60 inches. The projectile is shown in *fig.* 7. It has 12 leaden buttons on its exterior, that is, 2 for each groove. Though undoubtedly not nearly so perfect a weapon as either the Armstrong or Whitworth, it appears to have done good service in the late Italian campaign. It is also very simple in construction. The French have also a bronze rifled siege gun of about the calibre of 12-pounders, and have rifled some of their heavy iron ship guns. The success of the latter is doubtful, for in all the experiments in this country, unless strengthened, cast iron rifled guns have burst when fired except with very small charges.

Fig. 7.



RIFLEMEN (called by the French *tirailleurs*) were soldiers whose duties corresponded nearly to those of light infantry troops, but their muskets being rifled or grooved, the effect of their fire, within certain limits, was more certain.

In the preceding article we have stated what is known concerning the first use of rifled barrels on the Continent; and in the article Arms it has been shown that the duty of riflemen is indicated in the 'Observations' compiled by the Earl of Albemarle in 1646. The Anglo-American people are, however, believed to have been the first who organised corps of infantry armed with rifle-muskets, and during their struggle for independence the fire from those pieces too often took effect with fatal precision against the officers and in the ranks of the British forces. From that time the incorporation of bodies of riflemen with the armies began to take place among the nations of Europe, and it is now become a general practice. In the British service, the 60th, formerly called the Royal American regiment, is a rifle corps; and Manningham's rifle corps appears in the 'Army List' for 1801, but this became in 1803 the 95th regiment. In 1816 it was formed into the present Rifle Brigade, and placed under the command of Sir David Dundas, who had before been colonel of the 60th regiment. Subsequently to that year a regiment of native riflemen had been raised in Ceylon, and a rifle corps of cavalry at the Cape of Good Hope.

In 1853, after the Minié rifle was adopted into the service, it was intended to arm the whole of the infantry with it. In fact, the greater portion, if not the whole, of our army, were armed with it at the battle of the Alma; but the Enfield rifle having been decided on in 1854 by the committee appointed by Lord Hardinge, the whole of the infantry are now armed with it. Such being the case, the titles of Rifle Brigade and 60th Rifles become meaningless, though still retained on account of old associations.

The 60th and Rifle Brigade are however armed with a short Enfield and sword bayonet.

RIGEL. [Orion.]

RIGHT. This word occurs under some form in all the Teutonic languages; and bears a double meaning equivalent to the significations of the Latin word *jus*.

In its strict sense it means a legal claim; in other words, a claim which can be enforced by legal remedies, or a claim the infringement of which can be punished by a legal sanction. It follows from this definition that every right presupposes the existence of positive law.

The causes of rights, or the modes of acquiring them, are various, and can only be explained in a system of jurisprudence; for example, a person may acquire a right by contract, by gift, by succession, by the non-fulfilment of a condition. But every right co-relates with a legal duty. Thus a right arising from contract (for example, a contract to perform a service, or to pay a sum of money) is a right against a determinate person or persons; a right of property in a field or house is a right to deal with the field or house, availing against the world at large. On the other hand, every legal duty does not co-relate with a right; for there are certain absolute duties which do not co-relate with a right in any determinate person. Such are the duties which are included in the idea of police; as the duties of cleanliness, order, quiet at certain times and places.

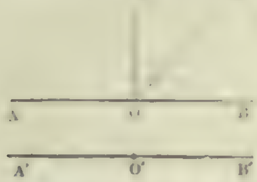
The word right is sometimes used, improperly and secondarily, to signify not legal but moral claims; that is to say, claims which are enforced merely by public opinion, and not by the legal sanction.

In this sense the right of a slave against his master, or of a subject against his sovereign, may be spoken of; although a slave has rarely any legal right against his master, and a subject never has a legal right against his sovereign. It is in the same sense that a sovereign government is sometimes said to have rights against its subjects, although in strictness a sovereign government creates rights, and does not possess them. In like manner, one sovereign government is said to have rights against another sovereign government; that is to say, moral rights, derived from the positive morality prevailing between independent nations, which is called *international law*.

We likewise sometimes hear of certain rights, styled natural rights, which are supposed to be anterior to civil government, and to be paramount to it. Hence these supposed natural rights sometimes receive also the additional epithets of indefeasible, indestructible, inalienable, and the like. This theory of natural rights is closely connected with the fiction of a social compact made between persons living in a state of nature; which theory, though recommended by the deservedly high authority of Locke, has now been abandoned by nearly all political speculators.

RIGHT. (Mathematics.) This term is applied in mathematical language to anything which is imagined to be the most simple of its kind, to distinguish it from others. Thus a right line is a STRAIGHT line; a right angle is the most simple and well-known of the angles used by Euclid: a right cone is one in which the axis is at right angles to the base: and so on.

RIGHT ANGLE. When two lines, at first coincident, are made to separate so that one of them revolves about their common extremity, the revolving line will in time become the continuation of the other. This angle or opening, made by a line and its continuation, would, we might suppose, be one of the principal angles considered in geometry, and should, according to the previously defined meaning of RIGHT, be called a right angle. But in the geometry of Euclid the word angle seems to have been essentially connected with the idea of a pointed corner, and we have no means of finding out that he considered a line and its continuation as making any angle at all. Instead of this angle, made by O A and O B, or the angle of opposite directions, he introduces its half, and calls it a right angle. Let A O C and C O B be equal angles, that is, let O C bisect the angle A O B, and each half is called a right angle. When the angle A O B is mentioned, it is as two right angles. All that is necessary as to the magnitude of a right angle has been given under ANGLE: we propose here to point out the effects of the forced manner in which Euclid avoids the angle A O B.



It is sufficiently evident that nothing can lose its right to be considered as a magnitude by augmentation: so that the opening of A O and O B, which is double that of A O and O C, must really be a magnitude of the same kind as the angle A O C. Now the consequences of preferring A O C to A O B, as a fundamental angle of reference, are as follows:—

1. The introduction of the apparently very arbitrary axiom, that "all right angles are equal," instead of the more simple and natural one that "two straight lines which coincide in any two points coincide beyond those points." It is as evident as that "two straight lines cannot inclose a space," or "two straight lines which coincide in two points, coincide *between* those points," that the same also takes place *beyond* those points." A moment's examination will show that this axiom immediately gives as a consequence that the angle A O B in any one straight line is equal to the angle A'O'B' in any other; or as Euclid would express it, the doubles of all right angles are equal whence all right angles are equal. And it is one consequence of leaving the natural route, that Euclid himself has assumed both the more complicated axiom which he has expressed, and also the more simple one by which he might have avoided it: for he nowhere shows that if O A be made to coincide with O'A', then O B coincides with O'B'. Some of his editors have supplied the defect by making it a consequence of "all right angles are equal," that "no two lines can have a common segment:" that is, by making the cart draw the horse.

2. The necessity of appearing to prove a particular case of a proposition which is taken as self-evident in all other cases. Thus Euclid never proves that C O D and D O B are together equal to C O B; while he has to spend a proposition in proving that A O D and D O B are together equal to A O B.

3. The necessity of appearing to prove a particular case after the general case has been proved. Thus to bisect a given angle is the general proposition of which to draw a line perpendicular to a given line from a given point within it, is the particular case. The construction of the latter is precisely that of the former: but the two results have to be obtained in two distinct propositions: it would be right enough to make them cases of one proposition.

4. The habituation of the student to neglect the angles greater than two right angles, by his never meeting with one *as great*. Two lines which end at the same point make two openings, one greater and the other less than two right angles; except in the intermediate case when both are equal to two right angles. Now Euclid does not positively reject the angle greater than two right angles, nor does he say that of two lines which meet, the angle which they make shall be always taken to be that which is less than two right angles. Had he had such intention, one of his propositions would have been positively false, to wit, that in any segment of a circle, the angle at the centre is double of the angle of the circumference. Had such been his intention, he would have said, "in every segment *which contains an angle less than a right angle*, the angle at the centre is double of that at the circumference." It is true that his proposition is, "In a circle, the angle at the centre is double of the angle at the circumference *when they have the same circumference for a base:*" and some may think that the words in italics exclude (as in one sense they certainly do) the segment which has an angle greater than a right angle; since this angle, and its central angle, that, namely, which is less than two right angles, do not stand on the same circumference as a base. Let this be so, then we throw the difficulty on another proposition, the 27th. It is there shown that "in equal circles, the angles which stand upon equal circumferences are equal whether they stand at the centre or *at the circumference.*" If no mention of angles greater than two right angles be intended in the previous proposition, then the one before us is not completely proved, but only when the angle at the circumference is less than a right angle. At the same time there seems to be, in some of the subsequent propositions, proof of a desire to avoid the angle greater than two right angles, and to subdivide proofs into particular cases in order to avoid the difficulty.

But are we not in fact to assume, without particular inspection, from the general tone of the first six books, that the angle equal to or greater than two right angles was never really meant, and that all propositions are to be taken with such limitations as the above restriction would render necessary? Let those who think so, look at the last proposition of the sixth book, in which it is shown that in equal circles angles are to one another as their subtending arcs. Now the criterion of PROPORTION, as given by Euclid, requires that, in this proposition, any multiple, however great, of the angles may be taken. Now a multiple of an angle may not only be greater than two right angles, but greater than a thousand right angles; and every such multiple must not only be really included in the demonstration, but considered as a magnitude, and compared with other magnitudes of the same kind. It is impossible that the writer of the fifth book should have been unable to bear in mind that the establishment of proportion demands that every possible multiple of the quantities asserted to be proportional should be admitted and compared with every other: and thus it is certain that Euclid must have meant to consider angles not only greater than two right angles, but even greater than four, or any other number. Some commentators have supposed that Euclid meant to omit all pairs of right angles from such multiples, and all semicircumferences from the multiples of the arcs; but this would only be a use of the axiom, that if equals be taken from unequals, the remainders are unequal, which admits the greater of the quantities mentioned to be comparable magnitudes: and that Euclid does consider them as such, is all that is contended for.

RIGHT, PETITION OF. [PETITION OF RIGHT.]

RIGHTS, BILL OF. [BILL OF RIGHTS.]

RIGIDITY OF ROPES. In estimating the powers of machines, it is frequently necessary to take into consideration the effects arising from the rigidity or stiffness of the ropes which pass over the pulleys or the axles of the wheels; and, in order to understand how this condition affects the relation between the moving power and the resistance, let it be observed that when a stiff rope is bent over the upper part of a wheel or pulley in a vertical plane, for example, the weights or powers applied at its extremities may not be sufficient to draw the descending portions into the positions of two vertical lines. Now, if one of the parts of the rope should take such a direction that a vertical line drawn through the weight attached to that part, cuts the horizontal diameter of the wheel or pulley at a point between the centre and one extremity of the diameter, and if, at the same time, the other part should take such a direction that a vertical line drawn through the attached weight cuts the horizontal diameter at a point beyond the extremity of the latter, the distances of these vertical lines from the extremities of the diameter being represented by x and x' respectively, the corresponding weights by W and W', and the radius of the wheel by R, the conditions of equilibrium, instead of being $W = W'$, will be

$$W(R-x) = W'(R+x').$$

But, if W be the weight which by descending raises up the other, the value of x is generally so small that it may be disregarded; so that we have, in the case of equilibrium,

$$W R = W'(R+x'), \text{ or } (W-W')R = W'x',$$

$$\text{or again, } W - W' = \frac{W'x'}{R};$$

that is, in order to put the system in a state of equilibrium, the excess of W above W' should be equal to $\frac{W'x'}{R}$.

The formula given by Coulomb to express the force necessary for overcoming the rigidity of a rope, or the equivalent of $\frac{W'x'}{R}$, is

$$\frac{r^m}{R}(a + bW');$$

r being the semi-diameter of the rope, a the force arising from the warping or twisting of the rope, and b that which depends on the tension arising from the weight W; the values of m, a, and b may be determined by experiments made with cords of different diameters; and thus x' may be found. M. Coulomb ascertained that for slender string, $m = 1$, and that for stiff cordage the value of m varied from 1·5 to 2; also, from some experiments made with ropes consisting of 30 threads and 2¼ inches in circumference, he found that the weights requisite to overcome the rigidity, when the ropes passed over a pulley 4 inches diameter, and were strained by weights equal to 25 lbs., 125 lbs., and 425 lbs., were 5 lbs., 8¼ lbs., and 23 lbs. respectively.

Unfortunately ropes of equal dimensions differ much in rigidity, so that little dependence can be placed on the results of general formulæ in estimating its value. White ropes when wet are more stiff than those which are dry, and the rigidity of ropes is greatly increased by tarring them. In general, the weights necessary to overcome the resistance of tarred ropes is proportional to the number of the threads of which they are composed. General Morin has latterly revised the observations of Coulomb and of Navier on the subject of the rigidity of cordage, and has published the results of his inquiry in his 'Aide Mémoire de Mécanique Pratique,' and in his 'Leçons de Mécanique Pratique.' These essays have been translated and printed in the 'Engineer's, Architect's, and Contractor's Pocket-Book,' and from them it appears that Coulomb's rules, tables, and formulæ were prepared on a rather confined view of the case. Morin's own tables and formulæ are given in the translation thus quoted.

RING. [ANNULUS.]

RINGWORM is the term applied to many cutaneous eruptions, and more particularly to those on the head. It is not now possible to determine to which of these the name was first applied; but it is probable that the species of *Herpes* which appear in the form of rings were thus designated, especially that which nosologists call *Herpes circinatus*. This disease is still often called ringworm, when it appears upon the forehead or scalp; but the same name is still more generally applied to the different forms of *Porrigo*, especially *P. larvalis* and *P. scutulata*. The descriptions of the diseases thus confounded under this name will be found in the articles HERPES and PORRIGO.

RINGS, COLOURED. [UNDULATING THEORY.]

RINMAN'S GREEN. [COBALT.]

RIOT. A riot is a misdemeanor at common law; and is defined by Hawkins to be "a tumultuous disturbance of the peace by three persons or more, assembling together of their own authority, with an intent mutually to assist one another against any one who shall oppose them in the execution of some enterprise of a private nature, and afterwards executing the same in a violent and turbulent manner, to the terror of the people, whether the act intended were of itself lawful or unlawful." The assembling together therefore in a case where the law authorises parties to meet and use force in concert, as for the purpose of suppressing rebellion or opposing the king's enemies, or as part of the posse comitatus, will not constitute a riot. Neither will a sudden quarrel occurring among a number of persons who have met together at a fair, or on similar occasions, constitute a riot. But if on the occasion of a meeting, lawful in itself, some act of violence in disturbance of the peace is afterwards proposed, and executed in concert by those who are assembled, they will be guilty of a riot. The enterprise must be of a private nature, not necessarily relating to an individual, but still having in view some minor and special, and not a general public object. The object may be, for instance, to redress a grievance said to be suffered by some particular person, or to pull down inclosures on lands where the inhabitants claim a right of common. For if the enterprise be for the purpose of redressing grievances throughout the kingdom, or pulling down all inclosures, the offence is not riot, but amounts to a levying of war against the crown, and becomes high treason.

Violence, if not of actual force, yet in gesture or language, and of such a nature as to cause terror, is a necessary ingredient in the offence of riot. The lawfulness of the enterprise operates no further than as justifying a mitigation of the punishment. It does not in any way alter the legal character of the offence.

Two minor offences of rout and unlawful assembly, which are similar to riot, are generally treated of under that head.

A *rout* is where parties have commenced but not accomplished an enterprise, and in such a way that if the enterprise had been executed, they would have committed a riot.

It is an *unlawful assembly* when great numbers of people meet together with such circumstances of behaviour as to raise the fears of their fellow-subjects, and endanger the public peace. An assembly therefore of a man's friends to defend his person against violence threatened to him if he appear in a public place is unlawful, as such conduct tends to produce a breach of the peace. But an assembly in a man's own house to protect him while there, or to defend the possession of it, is not considered an unlawful assembly. At common law the sheriff and all peace officers are bound themselves to make every effort and to command all others to assist them to suppress a riot. It seems also that where the emergency is great and immediate, private persons on their own authority may act, and even use arms for the same purpose. On such occasions it has not been usual for the military to take any part except in the presence and under the direction of a civil authority. They are not however by law disqualified for any duty or relieved from any responsibility which under the same circumstances attaches to other classes of their fellow-subjects.

Various acts of parliament have been passed for the purpose of giving atuhority to magistrates and others in suppressing riots, and restraining, arresting, and punishing rioters. The most important is 1 Geo. I., st. ii. c. 5, commonly called the Riot Act, which provides that "if any persons to the number of twelve or more, being unlawfully, riotously, and tumultuously assembled together to the disturbance of the public peace, shall continue so assembled for the space of an hour after the magistrate has commanded them by proclamation to disperse, they shall be considered felons."

The form of proclamation is given in the Act, and is to be read with a loud voice and as near as possible to the rioters. Persons who do not disperse may be seized and apprehended by any magistrate or peace-officer or any private person who has been commanded by a magistrate or an officer to assist. In case of resistance, those who are attempting to disperse or apprehend the rioters will be justified in wounding or killing them. It is felony to oppose the reading of the proclamation; and if the reading should be prevented, those who do not disperse are still guilty of felony, if they know that the reading of the proclamation has been prevented.

A prosecution under this Act must be commenced within a year after the offence has been committed. By 7 & 8 Geo. IV., c. 30, s. 8, rioters who demolish or begin to demolish a church or a chapel, a dwelling-house, or any other of the various buildings or machinery mentioned in that Act, are to be considered felons, and by 7 & 8 Geo. IV. c. 31, provision is made for remedies against the hundred in such cases, if to the amount of 30*l.*; but if the damage does not amount to 30*l.*, before justices at a petty sessions.

The action must be commenced within three months after commission of the offence; and to entitle the party injured to bring it, he must, within seven days after the injury done, go before a magistrate and give on oath all the information relative to the matter which he possesses, and also be bound over to prosecute the offenders.

With respect to unlawful assemblies of a seditious character, see SEDITION; TREASON.

RISK. In the theory of PROBABILITIES the risk of loss or gain means such a fraction of the sum to be lost or gained as expresses the chance of losing or gaining it: thus an even chance of losing 40*l.* is considered as a positive loss of one-half of 40*l.*, or of 20*l.*; and 2 to 1 for gaining 60*l.* is counted as two-thirds of 60*l.*, or 40*l.* If both these risks were encountered at the same time, the whole transaction would be considered as a gain of 40*l.*—20*l.*, or 20*l.*, since this is the sum which would be netted by every such transaction in the long run, and one with another.

The following is the method of ascertaining the effect of the division of risks. Let there be an adventure in which the chance of success is p, and that of failure $1-p$. Let failure produce the loss of £ n and success the gain £ m: then $pm-(1-p)n$ is the result of every such transaction one with another. Let this last be called M; it is required to estimate the probability that in s transactions the average effect (gain or loss, according as M is positive or negative) shall lie between $\mathrm{M}+l$ and $\mathrm{M}-l$. Calculate the square root of s divided by $2p(1-p)$; multiply this square root by l, and divide the result by $m+n$. Take the table in MEAN (using it as in PROBABILITY, col. 774), let the last result be A, then the corresponding B is the probability required. [WAGER; WEIGHT OF OBSERVATIONS.]

RITUAL (from *ritus*, in the sense of *consuetudo*), the book which directs the rites and ceremonies to be observed in celebrating divine service in any particular church.

RIVER. In a legal sense rivers are divisible into fresh and salt-water rivers. Salt-water rivers are those rivers or parts of rivers in which the tide ebbs and flows. Rivers are also divisible into public or navigable rivers and private rivers.

The property in fresh-water rivers, whether public or private, is presumed to belong to the owners of the adjacent land; the owner on each side being entitled to the soil of the river and the right of fishing as far as the middle of the stream. But this presumption may be rebutted by evidence to the contrary. If a fresh-water river between the lands of two owners gains on one side by insensibly shifting its course, each owner continues to retain half the river, and the insensible addition by alluvium belongs to the land to which it attaches itself; unless the lands of the proprietors on each side has been marked out by other known boundaries, such as stakes, &c. in the river. (Bracton 'De acquirendo rerum dominio,' 'Dig.' 41, tit. 1, s. 7.) But if the course of the river is changed suddenly and sensibly, then the boundaries of the lands will be, as they were before, in the midst of the deserted channel of the river. Special custom may also alter this general presumption of law. Though fresh-water rivers are presumed to be the property of adjacent landowners, yet no such owner can set up a ferry and demand a toll unless by prescription or by charter from the king. In early times also the king by his prerogative might prevent all persons from fishing or fowling in any river until he had first taken his pleasure there. This was effected by directing a precept to the sheriff commanding him to cause all persons to abstain from approaching the banks. By Magna Charta this prerogative was restricted to such streams as it had been exercised upon in the time of Henry I. Subsequently the custom was to name the rivers in the precept to the sheriff; among these was the Avon, at least that part which flows through Worcestershire. Eventually the prerogative fell into disuse. In those rivers which are navigable, and in which the public have a common right to passage, the king is said to have "an interest in jurisdiction," and this is so not only in those parts of them which are the king's property, but also where they are come to be private property; such rivers are called "fluvii regales," "haut streames le roy," "royal rivers"; not as indicating the property of the king in the river, but because of their being dedicated to the public use, and all things of public safety and convenience being under his care and protection. Thus a common highway on land is called the king's highway, and navigable rivers are in like manner the king's highway by water. Many of the incidents belonging to a highway on land attach to such rivers. Accordingly any nuisances or obstructions upon them may be indicted even though the nuisances be in the private soil of any person; or the nuisances and obstructions may be abated by individuals without process of law. It must not however be inferred that all the incidents of a land highway attach to such rivers. Thus, if the highway of the river is obstructed, a passenger will not be justified, as he would be in the case of a land highway, in passing over the adjacent land. And though a river is a public navigable river, there is not therefore any right at common law for parties to use the banks of it as a towing-path.

If a river which is private in use as well as in property be made navigable by the owner, it does not therefore become a public river unless from some act it may be presumed that he has dedicated it to the public. The taking of toll is such an act. Callis says that the soil of the sea and of royal rivers belongs to the king. But the expression, if intended to apply to all parts of the rivers where the public have a right of passage, appears too comprehensive.

But there is no doubt that in some such rivers the property may be in the crown; as it was in the river Thames, the property in which, both as to the water and the soil, was conveyed by charter to the lord mayor and citizens of London. And in all rivers as far as the tide flows, the property of the soil is in the king, if no other claims it by prescription. In navigable rivers where the tide flows, the liberty of fishery is common and public to all persons. (Hale, 'De Jure Maris et Brachiorum ejusdem'; Callis, 'On Sewers.')

The property in the mere running water is in no one; but the proprietor of adjoining land is entitled to the reasonable use of it as it runs by his land. "And consequently no proprietor can have the right to use the water to the prejudice of any other proprietor. Without the consent of the other proprietors who may be affected by his operations, no proprietor can either diminish the quantity of water, which would otherwise descend to the proprietors below, or throw the water back upon the proprietors above. Every proprietor who claims a right either to throw the water back above, or to diminish the quantity of water which is to descend below, must, in order to maintain his claim, either prove an actual grant or license from the proprietors affected by his operations, or must prove an uninterrupted enjoyment of twenty years."

RIVER ENGINEERING. The laws of hydraulics which apply to the flow of water in rivers may be briefly expressed as follows:—If a uniform velocity be once established, in a channel of whatsoever section, the same quantity of water must pass through that section in the same periods of time; and it follows from this that the velocity of the current must be increased proportionately to the diminution of the area, if the same discharge take place. As the rate of flow in open channels depends entirely upon gravitation, it must increase with the inclination; and, in order to maintain an equable discharge, the other conditions of cross section must be made to agree with this inclination. In channels, however, of uniform inclination and section, the rate of flow rapidly attains uniformity; for the friction of the water upon the sides and the bottom of the beds soon counteracts the accelerating force of gravity. It also follows, from the effects of the friction upon the wet contour, that the velocities of the different films of the transverse section are never uniform; because those which are in contact with the sides are retarded in their rate of flow, and they, in their turn, act to retard the flow of the films immediately around themselves; the maximum velocity being on the surface and on the axis of the deep water—the minimum velocity on the bed. Du Buat by direct experiment found that the mean velocity of a stream, in an open channel, might be expressed by the formula $v = cV$; in which v represents the mean velocity; c, a coefficient varying between 0·76 and 0·891; and V the surface velocity. In practice it is usual to consider that, for surface velocities of from 8 inches to 5 feet per second, $v = \frac{4}{5}V$, or that $V = 1{\cdot}25\,v$; but in large rivers it appears that, as in the Seine, $v = 0{\cdot}62\,V$; and in the Neva it is, $v = 0{\cdot}75\,V$; the horizontal position of the line of the mean velocity seems to range between 0·88 and 0·92 of the depth considered as unity. Du Buat also found that the bottom velocity called $U = 2v - V$, in which v and V retained their previous signification; and from thence we have, when $V = 1{\cdot}25\,v$, $U = 0{\cdot}75\,v$; or $v = 1{\cdot}33\,U$. It is the bottom velocity which acts by its transporting powers on the materials of the bed of a river, and has the greatest effect upon the stability of its banks.

In a channel of uniform velocity and section, if we call the discharge Q, and the sectional area S, v retaining its signification of the mean velocity, we have $Q = Sv$, and from this $v = \frac{Q}{S}$. The inclination of the bed, I, will be found by De Prony's formula $I = \frac{P}{S}(av + bv^2)$, in which P = the wet contour, or the developed length of the wetted surface; S = the sectional area; and a and b, coefficients, which he (adopting throughout the dimensions in metres and their subdivisions) made respectively 0·0000444 and 0·000309. Eytelwein made these coefficients $a = 0{\cdot}000024$ and $b = 0{\cdot}000365$, but it appears that De Prony's values are the most correct for small channels, whilst those of Eytelwein are the most correct for large rivers. If again we call the quotient of the transverse section S by the wet contour P the *mean radius*, and represent it by R, we have $R = \frac{S}{P}$, and the formula of De Prony gives us $RI = 0{\cdot}0000444v + 0{\cdot}000309v^2$; from thence we obtain $v = \sqrt{0{\cdot}005163 + 3233{\cdot}428\,RI} - 0{\cdot}07185$ or $v = 56{\cdot}86\sqrt{RI} - 0{\cdot}072$. Playfair gives this formula, in English feet and inches, $v = \sqrt{0{\cdot}023751 + 32806{\cdot}6\,RI} - 0{\cdot}1541131$; and from it the value of v can be easily ascertained if I and R be known, or we are enabled to fix the rate of inclination I requisite to secure a velocity such as shall ensure that $v = \frac{Q}{S}$ when the other terms are known.

De Prony's formulæ, modified, if needs be, by Eytelwein's observations, will serve not only to calculate the discharge, and the other conditions of the flow of water in a regular uniform channel, but also to calculate the conditions of the flow of water in rivers, provided a length of about 500 yards can be found upon it, where the channel is of a tolerably uniform section, and the velocity is regular. A cross section of the stream will give S and P, from whence R will be derived; and I will be ascertained by actual levelling. When the cross section is not constant the average area of a number of cross sections will suffice for ordinary calculations, and the inclination may at any time be ascertained from v by actual observation, when it is not possible to level the line of the mid-stream. If the river should happen to be divided into two branches, with marked inequalities of bed and flow, it would be preferable to consider each of them separately. For rough approximate calculations the volume of a river may be likewise ascertained by the formula $Q = S\,(0{\cdot}08\,V)$ in which S signifies as before the sectional area, and V the surface velocity; but it is essential that every possible precaution should be taken to secure a correct value for V.

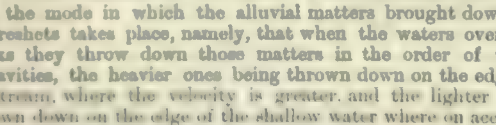
It must not be supposed that the transverse section of any flowing body of water is perfectly horizontal on its upper surface, because it will be found that immediately over the portion of the section where the greatest velocity prevails, the surface will be slightly raised above the level of the shallower portions of the stream. In small rivers it is not possible to distinguish this species of surelevation; but in larger ones it is at times strongly marked. A phenomenon of more importance to the stability of banks consists in the existence of a zone of still water, comparatively in close proximity to the shore in consequence of the greater resistance to the flow through the friction of the banks; and in this part of the stream may also be observed a series of small eddies produced by the impulsion of the current. The principal direction of these eddies appears to be directly opposed to that of the main stream; and moreover it will be found that when any obstacle is offered to the onward flow of the water, the latter will in the first place heap up against this object, and finally give rise to a distinctly marked counter current, technically known as a *back-water*. If the obstacle should extend across the whole stream, the upper surface of the water will assume a sensibly parabolic longitudinal section, the apex of which will be situated at a considerable distance up stream, and the axis upon the deep water-line. If the obstacle, however, should only be upon one bank, the back-water will not extend for any great distance; but it may frequently happen that the effect of the counter current would be so great as seriously to endanger the stability of the bank itself. The spurs, which are in many cases introduced for the purpose of defending the shores of rivers, when they extend far into the stream, produce this particular effect; and they may often be observed to give rise to a series of eddies, currents, and back-water, which wear away the shore at the points where they are joined to the land, on the upside especially. Another effect produced by a projection into the line of flow of a stream is that the portion of the current which does not go to form the back-water, is deflected from its course, and may perhaps be made to impinge in a dangerous manner on the opposite bank. At any rate the current at the foot of a spur into a main stream is sure to deepen the bed of the river at its foot, and to carry the channel towards the convex side of the bank; indeed this law holds universally, and in rivers it is always found that the deep water channel follows the convex side of the meanderings, and that the channel thus naturally tends to straighten itself by the more rapid abrasion which takes place against the projections. From these remarks it would follow that whenever it is desired to regularise the courses of rivers it is preferable to do so by means of longitudinal parallel walls, rather than by spurs; and that the direction of the new channel should be made as far as possible rectilineal, or at least with curves of very large radii. M. Defontaine observed on the Rhine that elbows of 8300 feet radius produced but small effects upon the bed, or banks, of that river, notwithstanding that they were composed of easily transported materials; and it may be inferred from this that a bend whose radius should be not less than twelve times the width of the maximum water line may be admitted in permanent works of this description. The above reasoning of course applies in the most exclusive manner to rivers whose flow is in only one direction; when the tidal action is brought to bear upon them, other conditions of regimen are developed to which attention will be called hereafter.

The nature of the materials of the bed a river may flow over will affect the chemical quality, and therefore the value, of its waters for such purposes as irrigation or water supply; and this, too, whether the materials taken up be so taken in solution, or merely in mechanical suspension. In WATER SUPPLY, attention will be called to the chemical portion of this inquiry; but at present it is advisable to dwell upon the merely mechanical effects produced, for the outlines of the beds of rivers depend mainly upon them. Now the longitudinal profile of a river almost always forms a species of parabolic curve, whose apex is in the high lands, and whose base is at the embouchure; so that the rate of flow is greater near the source than it is near the embouchure, the transporting and the erosive powers being also diminished in the same proportion. By the experiments of Du Buat we learn that the following materials will be carried forward by waters flowing with the velocities named in connection with them in the table:—

River mud, semi-fluid silt . .	Speed per second		0	feet	3	inches.
Brown pottery clay . . .	"	"	0	"	3¼	"
Common clay	"	"	0	"	6	"
Yellow sandy loam	"	"	0	"	8½	"
Common river sand . . .	"	"	1	"	0	"
Gravel, size of small seeds . .	"	"	0	"	4½	"
" peas . . .	"	"	0	"	7¼	"
" beans . . .	"	"	1	"	0½	"
Coarse ballast	"	"	2	"	0	"
Sea shingle, 1 inch diameter . .	"	"	2	"	2	"
Large shingle	"	"	3	"	0	"
Angular flints, size of hen's eggs .	"	"	3	"	3	"
Broken stones	"	"	4	"	0	"
Soft schistose rocks . . .	"	"	4	"	4	"
Rocks, with distinct stratification	"	"	6	"	0	"
Hard rocks	"	"	10	"	0	"

It thence follows that when the velocity of the river attains any of the above rates, it will be able to attack and remove by erosion the materials of its banks, which would remain in suspension at those velocities. In designing a system of river defences, however, attention must be paid exclusively to the *maximum*, not to the *average* velocity of the stream; because in flood time not only is the volume, but also the velocity, greater than at any other period, and the materials of which the banks are formed must be able to resist the transporting power of the floods. However, in consequence of their variable transporting power, rivers in their normal state flow over materials gradually decreasing in volume as they leave the steeper parts of their courses and approach their outfalls; and as those materials necessarily become at last very fine, especially in long flat plains, they offer little resistance to occasional floods, as may be observed in the deltas of such rivers as the Nile, Danube, Ganges, &c., which are composed of the fine mud brought down from the uplands, and in which the course of the stream continually shifts.

Some curious effects may be observed to take place with regard to the deposition of alluvial matters near the junction of streams draining areas of country situated under marked differences of thermometrical or hydrographical conditions; because the floods (or as they are technically called *the freshets*) frequently occur at distinctly different epochs, and thus, by reason of the freshet of one affluent ponding back the other a deposition of the matters in suspension in the retarded stream will be produced. It often happens that, under such circumstances, the accumulation of alluvial matters takes place in a manner to direct the local current against the banks in a direction essentially different from the main line of flow, the effect of which would be to divert the river from its original bed, to a greater or lesser extent, according to the resistance of the banks. There is another law with respect to the mode in which the alluvial matters brought down by floods or freshets takes place, namely, that when the waters overflow their banks they throw down those matters in the order of their specific gravities, the heavier ones being thrown down on the edge of the deep stream, where the velocity is greater, and the lighter ones being thrown down on the edge of the shallow water where on account of the friction the velocity is the least. The transverse section of a valley subject to freshets will be in fact something like the sketch here given. The banks will form slightly elevated ridges close to the water's edge, and the surface of the alluvial deposits will fall away gradually on either side; this condition may remain stable for some time, but there is always a danger from the tendency of the stream to create for itself a new bed in the lower level. On the Po, where the banks have been carefully maintained for centuries, the accumulation of the alluvial matters has taken place in the manner above sketched, but to such an extent as to create a real source of danger; for the banks of the river have been gradually so raised by the accumulation of alluvial matters, as to be in some cases as much as 40 feet above the extreme depression. [ALLUVIUM, in NAT. HIST. DIV.]



A few final general remarks with respect to non-tidal rivers may here be inserted, namely, that their volumes, even when they are of a comparatively stable character, vary within very wide limits. Thus the Rhone at Lyon, at times, flows with a volume of 7000 cubic feet per minute, at others with a volume of 203,000 cubic feet; the Rhine at Strasbourg varies between the limits of 9,500 and 164,000 cubic feet per minute; the Thames at Teddington between 5,400 and 15,000 cubic feet per minute. For the practical purposes of navigation, a current is considered to be slow when it does not exceed 1 foot 6 inches per second; a velocity of between 2 feet and 3 feet 6 inches per second is considered to be an average one; beyond the latter limit the velocity of the current is considered to be decidedly unfavourable to an upward navigation, and if the stream should flow at the rate of 6 or 7 feet per second, no boats can economically be made to work against it. When the rate of inclination of the bed of the river attains between 5 and 6 in 10,000, the velocity of the current becomes too great to allow of the navigation being carried on against it by the ordinary modes of traction; but by the use of steam tugs worked by high-pressure expansion engines, the Rhone has been navigated against the stream, even though its inclination has been on the *average* of its course from 7 to 8 in 10,000. Rivers which do not present a permanent depth of 1 foot 2 inches, with an available width of at least 14 feet, are not adapted to receive any kind of navigation, and they can only be rendered available for commerce by being canalized, or by being converted into what the continental engineers call floatable rivers. Streams of this kind occur in mountainous and woody districts, and are much used for the purpose of floating down rafts of timber, or such natural productions as are not likely to be injured by being occasionally submerged. When the width and depth of a river exceed respectively 18 feet and 18 inches, a barge navigation may be established, provided of course that the rate of flow be not unfavourable; and when the width and depth of the stream become respectively 60 feet and 8 feet, the river becomes navigable for sea-going vessels. The modes of propulsion to be adopted must depend upon local circumstances. In still water animal power is the most economical; steam is frequently used in deep water canals and river navigation; whilst sails, oars, and tides are frequently resorted to for this purpose in rivers adapted to their use.

In the lower parts of the courses of rivers discharging their waters into the ocean, and even to some extent in those discharging into tidal inland seas, a very marked interference takes place in the conditions of the currents, in consequence of the periodical tidal action. The tides themselves are produced by the periodical elevations and depressions of the level of the sea, caused by the combined action of the sun and moon, and under such circumstances they are naturally of greater amplitude on the shores of the larger bodies of water; on the Pacific, for instance, they are greater than they are upon the Atlantic; upon the latter, again, the tides are greater than upon the Baltic or the Mediterranean. The rising tide is called the *flood;* the falling tide, the *ebb;* and the returns of the tide take place twice in each consecutive interval comprised between the returns of the moon to the upper meridian. The mean length of this interval is 1·03505 day, so that the mean interval between two successive high waters is 0·517525 day, and the mean time of low water divides this interval again into two nearly equal portions. As in the case of all quantities susceptible of a maximum and a minimum, the increase or the diminution of the tides towards their limits is proportional to the squares of the time elapsed between the high and low tides. The height of the full tide on the sea-shore varies, normally, every day according to the phases of the moon; it is greatest at the syzigies, and least at the quadratures; but it is to be observed that in every place there is a species of retardation in the period of the high tide, as compared with the exact astronomical periods of the moon's changes, which is technically known by the name of the *vulgar establishment* of the place, and which depends upon laws to be noticed under TIDES. The rise of the high tides is usually proportional to the fall at low tides, but there is an irregularity between the heights of the two tides of the same day; the rise and fall at the syzigies is about double those of the quadratures, the former being called the *spring tides*, the latter the *neaps;* but it may be added, that the former are much increased when the moon is in perigee. An augmentation in the rise of the tide also takes place when the sun's declination is zero, or at the period of the equinoxes; and the greatest normal tide occurs when a new or full moon happens to occur near the equinox, when the moon is in perigee; and her action would be still further increased if her node should happen to coincide with the perigee. The other causes of the variations in the height of the tides may be neglected for the present, with the exception of those which are likely to affect their conditions in and upon rivers.

Thus, in cases where the tidal undulation is confined within a narrow gulf it becomes considerably increased in amplitude; and its reflection from the opposite shore may also increase that amplitude, especially in the recesses of such coasts. It is on this account that whilst at St. Helena in mid Atlantic, the rise is only 3 feet, and in the Northern Atlantic it never exceeds 10 or 12 feet, it is in the Bay of Mont St. Michel, 46 feet; in the Bay of Fundy, 50 feet; and in the Wye, at Chepstow, 60 feet. High winds, and especially the equinoctial gales, when they coincide with the spring tides may also give rise to great irregularities in the amplitude of the tidal range, and instances have even been recorded in which the tides of the quadratures have been raised by the effect of storms to a greater height than those of the syzygies. The disturbing effect of storms is, however, the greatest in seas with a small tidal range; as upon the French shores of the Mediterranean, where the normal rise of the tides is only from 6 to 12 inches, it is thus often increased to 3 feet. The most remarkable cause of disturbance in the range of the tides is, however, to be met with in the oceanic currents, and the manner in which they act varies in almost every case, producing some very singular interferences with the discharge of the upland waters, and with the deposition of the alluvial matters in the embouchures of rivers, whether the alluvions be brought from the sea, or from the interior of the country.

For instance, upon the shores of England we find that in consequence of the set of the tidal currents in the offing, the bars at the mouths of the rivers between Land's End and Portland, point from N.W. to S.E., as a rough general rule; between Portland and Selsea Bill, the in-shore tide runs in a direction opposite to that of the tide in the offing, and the bars of the rivers also point from N.E. to S.W. On the Atlantic shores of Ireland, the bars point rather S.E. to N.W.; they have the same direction on the western coasts of Scotland; whilst on the eastern coast of Scotland and of England, the bars upon the open coast point nearly from N.W. to S.E. In the mouth of the Thames two tidal currents meet, which have an origin separated by 12 hours' interval; so that not only are the day and night tides of that river equal in their amplitudes, but the alluvial matters transported by the tides are thrown down at the point where the velocities of the currents are destroyed, in banks which are constantly shifting. On the west coast of England again, there are in the rivers many instances of the double tide, arising from the reflection of the great tidal wave from a projection situated at a point beyond their embouchures, on the line of advance of that wave; and the conditions of the deposition of alluvial matters in these rivers are thus very different from the conditions ordinarily prevailing. Nor is this the only technical peculiarity connected with these rivers; because, in fact, the double tide is not so powerful as the normal tide for the purpose of carrying forward a barge navigation; but in another sense it is more favourable for the operations of commerce on a large scale, by reason of its retaining a great depth of water in docks and harbours, during the whole of the (so called) *slack-tide*. At Southampton, this slack tide lasts for nearly two hours; on the French coast the same phenomenon occurs at Hâvre, and in the Orne, during about 1½ hour in each tide. Great oceanic currents, wherever they exist, naturally produce analogous effects to these minor interferences with the progression of the tidal waves; but of course upon a much larger scale. A study of the history of the deltas of such rivers as the Nile, Ganges, Indus, Irriwaddy, Amazonas, Mississippi, &c., would be necessary for any one who desires to become acquainted with this important detail connected with hydraulic engineering. The actual records of the changes in the delta of the Rhine and of the Scheldt, would be of great interest and value also to the student; because they have been more closely and more scientifically observed than the changes which have recently taken place in other rivers of similar magnitude.

In the rivers exposed to the action of a complicated series of tides and currents, it is far more difficult to maintain a clear navigable channel than it is in rivers wherein the disturbing causes are more simple; and bar rivers, although extremely dangerous during stormy weather, are sometimes less inconvenient for the ordinary purposes of commerce than are those which, like the Thames, the Scheldt, or the Seine, are exposed to the injurious effects of the shifting sands thrown down at their embouchures. It is, moreover, to be observed that in the majority of cases the oceanic currents bring into the sheltered bays they meet with, a greater quantity of alluvial matters with the flood tides than the ebb tide can remove; and there is on this account a tendency in all such bays to silt up, a tendency which may distinctly be traced in the three rivers just mentioned. The maintenance of a navigable channel in these cases becomes a matter of difficulty, and it can only be effected temporarily by natural means, by securing the greatest possible scouring action of the tidal wave. The efforts of hydraulic engineers for this purpose should therefore be directed rather to concentrate the flow of the water in one well proportioned channel, than to secure merely a large volume of tidal water, without reference to the conditions of velocity it may be possible to impress upon the latter.. For this reason it is preferable, as a general rule, in designing works for the improvement of the navigable channels of rivers discharging their waters in tidal seas, to limit the width of the water-way in the lower portion, so as to drive the tidal wave as far inland as possible; and for the same reason every interference with the direct transmission of the tide is objectionable. Many illustrations of the truth of these propositions might be found on our own shores; but the success of the works executed for the improvement of the Clyde, Tyne, Seine, &c., must suffice to prove that the most important condition for the maintenance of a clear tidal navigation is, that the water should always possess a uniform velocity throughout its longitudinal and its transverse sections. In cases like the one which occurs at the mouth of the Tyne, where the passage through which the flood tide enters is contracted by the long bar extending from one shore nearly the whole width of the river; and where the flood, once admitted, can suddenly expand itself over a wide bay, it will be almost impossible to prevent the formation of alluvial deposits both from the sea and from the land; and if a second contraction of the water-way should take place abruptly above the inner bay, the peculiar phenomenon known by the name of the *eagre* or *bore* may be observed. The bore, in fact, is caused by the sudden influx, into a narrow channel, of a large volume of water flowing with considerable velocity, which rises in the form of a sudden wave, and constitutes a serious source of danger to the small craft navigating the rivers where it exists. On the Hoogley and on the Amazonas the bore sometimes rises almost literally like a wall of 12 feet in height; on the Severn and the Seine it is often 6 feet high, and advances inland at the rate of about 6 miles per hour; on the Trent the eagre often rises as much as 8 feet, at Gainsborough, and there are even rudiments of the bore to be detected in the Thames. The bore of the Seine has been diminished by the works lately executed for the regularisation of the bed of the river above its embouchure, in the bay of Hâvre. [BORE.]

The practical rules for the improvement of a river must evidently, from what has been said above, be susceptible of endless varieties, according to the nature of the stream, and the purposes to which it is intended to be applied. Even if no direct commercial benefit is anticipated from such operations, it must always be desirable that the flow of water should be kept as regular as possible, and the bed of the stream should be made to render the greatest amount of service as an outfall for the surface drainage. There are, however, few rivulets which might not be made to render service for irrigation purposes, and directly the flow of water becomes sufficient to allow the establishment of water-wheels, working occasionally or continuously, the streams become of great economical value. It is difficult to discover how the right of property in running waters has been established; and it is a matter of serious doubt even whether the existence of such rights be not in itself frequently a source of public inconvenience; but as this state of things has existed from time immemorial it must be dealt with in its actual form, if it were desired to improve any particular stream. The precise objects aimed at in such operations are mainly to retain the waters in their beds, and to regularise the conditions of the flow of water in the channels; to prevent inundations, in fact, and to keep the stream constantly in a state which should enable it to perform the services it is applied to.

As to the prevention of inundations, that object may at times be effected by establishing, artificially, a system of reservoirs in the upper parts of a river's course, which should perform the same function which the Swiss lakes perform for the rivers coming from the Alps, that is to say, should store the storm waters during the winter months for the purpose of distribution in the dry season. Works of this description have been executed in the East, and they have been recommended for France; they might be very advantageously introduced in our own colonies, and especially in South Africa and Australia. In RESERVOIRS the modes of executing this particular class of works has been alluded to; and the reader may be referred, for further information on the subject of their influence upon inundations, to Frisi's work upon 'Torrents,' to Valles, Savigny, Suzell, Hun, Ribbe, Babinet, &c., who have written at length on the inundations of France. For the present it may suffice to add, that when the rivers become of sufficient volume to cause dangerous inundations, there seems to be less danger when the banks of the river are dressed off at the height of the ordinary winter flood lines (so as to allow the waters when they exceed that level at once to flow over the country), than when the waters are confined within narrow banks raised to a considerable height above the surrounding lands. In some places on the banks of the Po, a river subject to violent floods, the banks are made of two descriptions: "in froldi," when they are raised to the necessary extreme height at once, and on the margins of the stream; and "in golene" when they are raised at a great distance from the margins, so as to interfere as little as may be with the spread of the waters. The former course is adopted when the valley of the river is narrow and the foundations are good; the latter, when the valley widens out, and there is any danger of the undermining of the banks. A double system of dykes, such as the one adopted in Piedmont, might perhaps save the dwellings upon the banks of the Rhine and of the Maas, from the periodical returns of their disastrous inundations; at any rate it would materially increase the security of the banks themselves when ice floats down in large quantities, as the piling up of the hummock ice is more injurious to the light earthen or fascined embankments of those rivers than even the floods themselves.

The embankments thrown up for the purpose of protecting the submersable districts on the side of a river must be made of a great thickness, and with every imaginable precaution to ensure their stability and their water tightness. The surface exposed to the wash of the current must be protected if the embankment should be composed of easily transportable materials, by stone pitching, planking, concrete, wattling, cribwork, or by fascines, tunnages, or clayonnages, in the manner practised by the German, French, and Dutch engineers. As a general rule the tops of these banks are made wide enough to carry a road; and it is essential to make provision for removing from the landward side the drainage waters which may there accumulate; it would be better to effect this operation by lifting the drainage waters over the bank instead of passing them under it. Local considerations must, however, regulate the choice of all these details, as well as those connected with the materials to be used in the formation of the bank itself.

For navigation purposes the improvement of small streams in thinly peopled, mountainous, and woody districts, is almost forcedly limited to converting them into floatable rivers; and this is often effected by throwing a set of dams across the rivers, so as to form as it were locks of still water, in which the timber can be made into floats, and moved towards the sluices formed in the dams, which are opened whenever there is a sufficient accumulation of water to float the timber to the next pond. The width of these sluices is usually made about 20 feet, and the fall varies between 3 and 4 feet; but as the sluice-gates are opened suddenly and the waters escape as it were with a flash, it is not necessary to make the fall great. There are some very good works of this description on the Yonne, above Auxerre; and the dimensions of the one at Régilbert may perhaps be added, as a model for our own colonial engineers. The passage and sluice are formed by carrying out walls from both banks, in a species of funnel shape, with its wider mouth towards the upstream, of 233 feet in width, and a length of about 210 feet from its commencement to the passage, which is 20 feet in width and 33 feet in length to the sluice. Beyond the sluice the wing walls open out for a distance of 20 feet, and at the end to the down stream they have an opening of 24 feet; a floor, for the purpose of obviating the inconvenience of the cataract produced by the flash of water, is continued beyond the wing walls; the water is ponded up to a height of 4 feet, and the sluice is opened, and in a fit state to pass a raft, within about eight minutes. Occasionally it is desirable to combine sluices of this description with locks, or, in fact, to combine a navigable and a floatable system. In these cases the lock should be placed in the still water, on the opposite side to the flashing sluice; the latter being itself near the head of the lock chamber, and the tail of the lock being placed at a sufficient distance from the end of the dam to obviate any danger from the back-water, or cataract of the sluice.

The most generally successful mode of improving rivers of small and irregular volume is, however, their conversion into still water, or canal navigations, by the construction of locks, waste weirs, and moveable dams. The positions which are the best fitted for the construction of the locks are upon the subsidiary channels formed by the islands in the mid stream of the river; and, unless some peculiar local circumstances should intervene, it is customary to form the dam and waste weir near the head of the smaller branch, and to place the lock at the lower end of the island; so as, in fact, to convert the smaller branch into the navigable channel, and to leave the wider branch as the storm or waste water passage, or *goit*, as it is technically called. The principles of construction of locks, &c., are of course the same in these cases as in canals [CANAL]; and perhaps this portion of the subject may be dismissed, by saying that the only special works required for river navigations are those by means of which sudden floods are allowed to pass; for especial care must be taken to guard against the formation of cataracts on the down side of the lock gates. The style of moveable dam used upon the upper Seine appears to be one of the most satisfactory of any yet tried, and it might advantageously be adopted on many of our colonial torrential rivers. Their mode of construction has been described in a special treatise, by their author, M. Poirée, but a brief account of them will be found in the 'Aide-Mémoire of Military Sciences,' article, River Navigation.

The position of the towing-path is, after all, one of the most important parts of the operations connected with the improvement of the navigation of an inland and non-tidal river; and it may be stated that this path should be placed, wherever it is possible so to do, by the side of the deepest water, and immediately upon the banks of the river. The theoretical conditions required for such paths are, that they should be exposed to as few impediments to the passage of the tow-ropes as may be, and that the direction of the haulage should not be too oblique. It is desirable to keep the paths under the wind, in order to avoid the action of the latter upon the boats; and when bridges are erected, to carry the paths under the land arches, in order to avoid the necessity for casting off the ropes. The width of the principal path should be about 12 or 13 feet; and if, in consequence of the existence of any rapid or current, it should be necessary to form a second path, so as to allow another rope to be thrown out to keep the boat's head well in the centre of the stream, the second path may be made only 6 feet 6 inches wide. The height of the towing-paths should be made such as to allow of their being overflowed directly the river rises to such a height, during floods, as to render the navigation dangerous; or perhaps a safe general rule would be, to keep the top of the path only 2 feet above the ordinary winter flood line. Great attention is required in the maintenance of the banks and of the roadway of the towing-path, especially if a rapid navigation be maintained; the banks in this case should be pitched, and the surface of the roadway macadamised. Secondary streams or small affluents should be bridged over, so as to avoid the necessity for casting off the tow-ropes on approaching them.

In rivers with light and easily moved beds, and which are subject to violent floods, the navigable channel will be found to run between numerous islands, and occasionally to shift from one to the other bank of the stream. In such cases it frequently becomes necessary to rectify the bed by forming a new channel, or to fix the current in its original direction by works which should confine it in one of its previous channels. This class of operations is one which requires consummate skill, for the nature of the foundations is such as to render it more than usually difficult to contend with the undermining action of the stream itself, and any injudicious diversion of the current will in all probability endanger the banks of the river for a great distance. The most simple rules of a general nature hitherto applied in settling the dimensions and directions of new channels may be stated as follows: it being always observed that local circumstances may modify their application in a very serious manner. Firstly, with regard to the conditions of flow in the channels, it is known that the velocities vary in the inverse ratio of the cube roots of the widths; and secondly, that the cubes of the depths are in the inverse ratio of the widths; in practice the capacity of the new channel should be made equal to that of the ancient one, but the capacity in question should be obtained, wherever it is possible, by increasing the depth at the expense of the width. All obstacles to the navigation, in the shape of trees, rocks, shallows, &c., should be removed; and the new channel should be connected with the old one by curves of considerable radius. The banks of the new channel on the side opposite to the towing-path should be made in such a manner as to allow the water to flow into the bye-wash as soon as the floods bring down an abnormal quantity of water; and it is very seldom, in ordinary river-barge navigations, that the crowns of the dams forming the bye-washes are raised more than two feet above the full summer level of the stream. Excellent examples of the mode of constructing these lateral banks are to be found in Smeaton's works on the Carron, Telford's on the Weaver, and D. Stevenson's on the Ribble, though in some of these cases the tidal action intervened; perhaps the best treatises to be consulted on this subject are, however, a 'Mémoire on the Rectification of the Bed of the Midouze,' in the 'Annales des Ponts et Chaussées,' 1831; a 'Mémoire on the Defence and Improvement of the Navigable Channel of the Rhine,' by M. Defontaine, in the same publication for 1833; in Sganzin's 'Cours de Construction;' and in Brook's, Calver's and D. Stevenson's treatises on River and Canal Engineering.

The treatises last mentioned are, it is to be observed, more particularly composed with reference to the engineering works required for the improvement of the tidal or of the salt-water portions of rivers; but it may be added that, in all cases, the results of experience show that the most certain mode of regularising and deepening the bed of a river is by the establishment of continuous longitudinal embankments. With respect to the tidal or marine parts of the streams, the only remarks to be made in addition to those previously applied in the course of this notice are, that so long as the rivers discharge into seas wherein the tidal action takes place without interference, the navigation may be improved, and the depth of the channel maintained in an efficient state simply by the construction of lateral embankments, diminishing gradually in width according to the quantity of water flowing inland. Any sudden widening or contraction of the channel is injurious; but nature will eventually remedy the former disadvantage, for alluvial matters will be thrown down in the species of bay thus formed, and all that will then be required will be to keep the main channel open, in the precise direction required, by works of comparatively easy execution. In rivers like the Thames and Medway, the Seine, Rhine, &c., where the flood tide is enabled, by the peculiar laws of the deep sea currents, to carry in more alluvial matters than the ebb can remove (and in discussing this question of the movement of alluvions in rivers, the difference in the specific gravities of salt and of fresh water must not be lost sight of), in such rivers there must always be a danger of the channels becoming gradually silted up. The proper course to be adopted in such cases is to combine an efficient system of dredging with a regularisation of the upper portions of the channel, so as to develope and to concentrate the scouring action of the tide and of the current to the utmost extent; but it must always be understood that rivers placed under the action of this peculiar set of laws can only be kept open by the exertion of great skill, energy, and enterprise. It is true that hitherto little inconvenience has been felt in the Thames; in the Medway, however, a gradual shoaling up of the tidal portion of the river has been observed; the mouths of the Rhine are successively being choked; the mouth of the Scheldt is becoming less and less adapted for large vessels; and the Seine has been shown to present this peculiar characteristic, namely, that even at Rouen the alluvial mud consists rather of materials brought in by the flood tides from the sea, than of materials brought down from the interior by the fresh water. It may also be added, that, as the height and volume of water in a tidal river depend far more on the quantity of the tidal stream than upon any supply from the interior, it is comparatively easy to calculate the height to which the water may under any circumstances rise; and, when this has been ascertained, the banks on either side should be carried above the highest water-line; where towing-paths are used in rivers of this description, they should, if possible, be formed on both sides. A tidal current of about two to three miles per hour is usually considered to be advantageous for the trade of a river; and it is to the extraordinary facilities offered by the tides of the Thames that we may attribute the singular form of barge used upon it. These barges are in fact little better than logs which float on the top of the tide, and they contrast strangely with the barges used on the Seine, Rhine, Rhône, &c., which are built in such a way as to offer the least possible resistance to the current they are obliged to encounter beyond the limits of the tidal action.

Much information on the subjects alluded to in this article is to be found (in addition to the works already named) in Robison's *Mechanical Philosophy*; in Ellet's *Mississippi and Ohio Rivers*; in the *Raccolta dei Autori Italiani chi trattono del moto del acque*; Weibeking's *Theoritische Practische Wasserbaukunst*: De Prony's *Nouvelle Architecture Hydraulique*; D'Aubisson's *Hydraulique*; General Baird Smith's *Reports*, and his works on Irrigation, &c., &c.

RIVER IMPROVEMENTS. [River Engineering.]

RIVERS are the flowing waters which bring to the sea, and sometimes to a lake, the waters which are collected within a certain portion of the earth's surface. The country which is thus drained by a river is called its *basin*, as the river runs in the lowest part of it, and the country rises on all sides with greater or less steepness, in the fashion of the sides of a basin. The margin of such a basin generally lies contiguous to the basin of another river, and thus constitutes the boundary-line of the two basins. From these margins the waters descend on both sides towards their respective basins, which are separated by them, and hence the whole line of these margins is called a *watershed*, properly the *water-parting*. [Watershed.]

The basins of rivers vary greatly in size. A *brook* is the name commonly given to rivers of the smallest description. When such a river rises near the sea or near a large river, into one of which it flows after a short course, it consequently drains a very small surface. If the waters should be increased by those of another brook, the name of brook is changed for that of *rivulet*. The basin of a rivulet is therefore more complicated than that of a brook. One or more brooks descend from the margin of the basin, and by uniting their waters with those of the rivulet, increase its volume. When several rivulets unite and so produce a considerable volume of running water, this watercourse takes the name of *river*. But all such rivers do not reach the sea, or even a lake; most of them join other rivers, and thus a large river is produced. This last mentioned large river is called the *principal river*, and those which increase its waters are called, with respect to it, *affluents* or *tributaries*, and sometimes *feeders* or *branches*. In Syria and Arabia and north eastern Africa, the *winter-brooks*, or small streams which flow only in the winter or the rainy season, are called *wadies*, a term frequently met with in the works of travellers in these countries.

The first waters of a river are generally derived from a spring, which breaks out at the foot of a declivity, or on the side of some hill or mountain; and sometimes from a swamp or a lake. This is called the *source* of a river. From this source the river descends through the lowest part of its basin until it terminates its course in the sea, a lake, or another river, and this termination is called the *mouth* of the river. The cavity in which the running water flows is called the *bed* of the river, and the solid land which bounds this bed is called its *banks*. The *head-streams* of a great river are those, proceeding from their sources, which by their union or confluence produce the first principal stream, with which another principal stream may be afterwards *confluent*, or which may receive tributaries.

Most large rivers have their origin in very elevated mountains, or on high table-lands, in descending from which a great difference with respect to the rapidity of their course, and the nature of the country through which they flow, is observed. Accordingly geographers divide the whole of the course of such rivers into three divisions, the *upper*, *middle*, and *lower* course.

The *upper* course of such a river lies within a mountain region, and its source is consequently at a great elevation above the sea. The waters run with greater or less velocity, according to the greater or less extent of the mountain region, and the greater or less rapidity with which the whole region declines towards the country to which the whole course of the river is directed. When the elevation of the mountain-region decreases with great rapidity, the current of the river is extremely rapid, and presents a quick succession of cataracts and rapids. The force of the current is so great that pieces of rock of considerable size, which are frequently detached from the overhanging masses, cannot resist it, and are carried down by the current, until they reach a point where the rapidity of the descent begins to diminish. The mountains which constitute the banks of the river often rise several thousand feet above it, and their bases are united by slopes forming an angle, over which the water runs on bare rocks, without the least covering of earth. Thus the river does not flow in a valley, but in a cleft or ravine, which cuts deep into the mountain masses. Sometimes there is space enough for a path between the river and the mountains, but in many places this space is only obtained by artificial means, as by cutting away a projecting portion of the rock, or by making a tunnel through it. Where either of these means cannot be applied, the path is continued over the bed of the river by a wooden bridge of greater or less extent, until a place is reached which offers sufficient space for a path on the sides of the rocks. The course of the river is generally in a straight line, but sometimes it makes short and abrupt bends which form acute angles. In the last-mentioned case it is, almost without exception, observed that the mountains which inclose the river have on one side a projection, and on the other a recession, which correspond so exactly that if it were possible to unite the two mountains, the projecting would exactly fit into the receding part. This peculiarity in the formation of the ravines of mountain streams was observed by the Spaniards in the Andes of South America, who called them *quebradas*, or broken; by this term tacitly assuming that the phenomenon had been caused by a violent disruption of the mountains. This description of mountain-streams and their ravines applies particularly to those of the western Alps along their southern declivity, to those rivers which constitute the upper branches of the rivers Doria and Sesia, to the valleys of Anzasca and Vedro on the southern side of the great road of the Simplon, and to the still larger valley of Aosta, through which the road leads from Switzerland to Italy over the mountain-pass of the St. Bernard. The military road of the Romans was made through the Val d'Aosta; but in these parts it was only practicable for beasts of burden. Such deep ravines not only occur between the gigantic elevations of a high range, but likewise in the elevated table-lands. According to Dr. Beke, the rivers of Abyssinia, nearly all affluents of the Nile, or of its great tributaries, in the early part of their course, flow over the level surface of the table-land, being little more than muddy brooks, nearly without water in the dry season, but overflowing their banks so as almost entirely to inundate the plain country during the rains. They escape from the plateau by precipitous falls of 80 or 100 feet or more, into fissures in the rocky surface, at first only a few yards in breadth, but gradually opening to the extent of several miles, down which the stream hurries in a succession of falls and rapids, so as to descend several thousand feet in the course of a few miles. In these deep-cut valleys, the rivers thus soon reach a depression of 3000 or 4000 feet below the general level of the table-land. The larger valleys are of considerable width; that of the Abai, or Nile of Bruce, the upper course of the Bahr-el-Azrek, or Blue River [Nile, in Geog. Div.], for example, is at least twenty-five miles between the extreme points where it breaks away from the table-land on either side. "And as the country is wild and irregular," remarks Dr. Beke, "it is easy for a traveller, who has not taken a comprehensive view of the entire region, and who finds himself shut up in such a valley with a mass of broken country surrounding him, to believe that in ascending from the river he is crossing a mountain chain; whereas, in reality, he has merely reached the continuation of the table-land which he had left on the opposite side of the river." The great rivers of India present corresponding phenomena to those of the East African table-land, but on a more immense scale. [Plains.] Humboldt observes that the plain of Quito, which is nearly 10,000 feet above the sea, is intersected by ravines, which in some places sink so deep that their bottoms are hardly more than 2000 feet above the sea-level; and he adds that some of them are so narrow as not to contain the smallest cultivable space. Similar ravines intersect the table-lands of Guatemala and Anahuac, where they are called *cañadas*, a term, however, which does not imply the existence of rivers in them or relate to that circumstance, but merely to the abrupt descent of land.

When the mountain-region through which the upper course of a river lies descends with less rapidity, and consequently occupies a much greater extent of country, the mountain-streams, as well as their banks, present very different features. Both the streams and the banks show that the descent of the whole mass is not by a regular slope, but is formed by an alternation of plains and declivities; in ascending such a mountain-stream, it is found that in certain places the rocky masses approach so near to the banks, as to leave hardly room enough for the river, and in these narrows the current is extremely swift, and generally a contineal rapid, interrupted by falls of moderate height. These narrows however rarely extend more than a few miles. Above them the mountains recede to some distance from both sides of the river; and thus a basin is formed, in the middle of which the river flows with a comparatively slow current, not over bare rocks, but over a gravelly bed, and between low banks of earth. The bottom of the basin is level, or descends with a gentle slope, and may be cultivated or used as pasture-ground. In some of the rivers which descend from the central and eastern Alps, this alternation of narrow passes and basins occurs several times. Thus the Reuss, along which the great road runs which leads over the mountain-pass of St. Gothard, rushes with incredible velocity through the ravine of the Hospendal, and falls 1800 feet before it reaches the basin of the valley of Ursern, which is nearly eight miles long and more than half a mile wide, and in which it runs with a gentle course. At the northern extremity of the valley of Ursern the river enters the second narrow at the Urnerloch. This narrow, which extends about three miles to Geshinen, is extremely contracted, and within these limits the river descends 1074 feet, forming a succession of small cataracts. Below this is the basin of the Krachenthal, which is not so wide as that of Ursern, and about six miles long. The course of the river within this basin is rapid, but there are no cataracts. From this valley the river escapes by the third narrow, which is about four miles long, and also very contracted; it terminates at the village of Am-Stäg, where the Reuss enters the valley of Uri, in which it flows until it mingles its waters with those of the lake of Uri (Urner-see), as the southern part of the Vierwaldstädter-see is named. The same conformation is observed in the southern declivity of the Alps, where the river Ticino descends from the mountain-pass of St. Gothard. This river runs in a ravine from the Hospendal to Airolo, in which it descends about 2880 feet. It then enters the upper valley of Leventina, which is about seven miles long and half a mile wide, and in which the river is rapid, but has no cataracts. It issues from this valley by a narrow about two miles long, between Il Dazio and Faido, where a series of beautiful waterfalls occur, and the ravine is so narrow that an artificial road has been cut on the adjacent mountain called the Platifer. At Faido the Ticino enters the middle valley of Leventina, in which it flows with great rapidity to Giornico, a distance of about fifteen miles, but without forming any falls. The valley is less than half a mile wide, and often interrupted by rocks. Above Giornico the river enters a short narrow, at the outlet from which it forms cataracts, and then reaches the wide valley called the Lower Valley of Leventina, in which it flows with a comparatively gentle course to Lago Maggiore. The greater number of the rivers which originate in the Alps and Pyrenees are of this latter description. The basins which occur in these river-valleys may at some remote period have been filled with water, and this may have been drained off by the rivers forming an outlet for the waters by the narrows which now connect their basins with one another

A remarkable peculiarity of most of the rivers joining the Nile, dependent of course on the structure of the country through which they flow, is that they have a circular, or rather a spiral course, so that after having described a curve of greater or less extent, round the isolated mountain masses which break the uniformity of the table-land of Abyssinia, they return upon themselves at a comparatively short distance from their sources. As instances of this may be mentioned the Mareb, or Khor-el-Gash, the Bellegas, the Abai, the Gibbe, the Godjeb.

In some places the elevated mountain-ridges border immediately on low plains. In such cases the rivers cannot be said to have a middle course; for as soon as they reach the plain their character is changed, and the rapid torrent is converted into a gentle stream. Thus the Marañon, after issuing from the Pongo de Manseriche, and entering the great plain, flows slowly through the alluvial level; and the Ganges, after leaving the Himalaya Mountains, at Hurdwar, flows with great bends through the immense plains of India. [HINDUSTAN, in GEOG. DIV.] All the rivers which descend from the southern declivity of the Alps to the plain which the river Po traverses are of the same description. In most cases, however, the mountain-regions are not in immediate contact with the plains, but are separated from them by hilly tracts, and that portion of the course of a river which lies through such a hilly region is called the *middle* course. The rocky masses rarely approach the bed of a river which has a middle course, but retire to some distance from them, so as to form between the higher grounds a wide valley, which the inundations of the river have covered with a thick layer of alluvial soil. It is remarkable that the highest ground of these valleys occurs, without exception, on the very banks of the rivers, and that the land slopes from them towards the base of the higher grounds. Accordingly the inundations generally cover the lower tracts, which are at some distance from the river, to the depth of several feet, while the banks are still above the surface of the water. The slopes of the higher grounds, which may be considered as the outer banks of the river, because they fix a limit to its inundations, are generally gradual, and covered with vegetation. The current of the river itself is gentle. This change, when compared with that of the mountain stream, is partly due to the more gentle descent of the hilly region, and partly to the form of its course. The bed of the river rarely lies in a straight line, but continually forms bends, which are not acute angles, as in the case of the mountain-streams, but have only a small curvature, so that the river runs through the valley in a serpentine course. This circumstance renders the course of the river much longer than it would be if it flowed in a straight line, and consequently diminishes the fall and the rapidity of the current.

It is observed that rivers form numerous small islands and sand-banks a short distance below the place where they issue from the mountain region. Thus the Rhine, between Basel and Kehl, opposite Strasburg, and the Amazonas, below the Pongo de Manseriche as far east as the mouth of the Yapura, and the Mississippi, between the mouth of the St. Peter river and that of the Missouri, form islands and sand-banks. This is easily to be accounted for, by observing that the river, on issuing from the mountains, retains a large quantity of earthy matter in suspension, which subsides when the current decreases in rapidity. This sediment forms islets and sand-banks. Though it rarely happens, as already observed, that the rocky masses approach close to the banks in the middle course of a river, yet this generally occurs several times, and at such places the river usually forms rapids and whirlpools. A ledge of rocks traverses the bed of the river in some places. Such ledges occur in the Danube at Passau, near Neuburg above Vienna, near Presburg in Hungary above Pesth, and at Orshova, or Orsova, on the boundary line between Austria and Turkey. On the Rhine they occur only between Mainz and Bonn, where the river is traversed by three ledges, at Bingen, at St. Goar, and near Andernach respectively. Such ledges are found in nearly all the large rivers of Europe. The elevations by which they are produced are sometimes connected with ranges of hills.

Ledges of this description occur in many of the Atlantic rivers of the United States, as the Potomac, the James River, and others; and they mark with precision the passage of the rivers from the undulating or hilly region to the low plains along the coast. There are of course rapids where these ledges occur.

The *lower* course of rivers usually lies through a plain. In general there are no hills which constitute the outer margin of its course, and consequently there is no bottom or valley through which it runs. The banks are very little raised above the surface of the waters, and the level ground extends to a greater distance. The current is slow, the fall being very small. Thus it was observed by La Condamine, that the Amazonas from the narrow at Obydos to its mouth, a distance of 700 miles, does not fall quite 12 feet, or little more than 0·2 of an inch per mile. It can hardly be conceived that a river with so small a fall could propel its waters, and as the current of the Amazonas is considerable, it can only be accounted for by supposing that the enormous volume of water which the river brings down, drives on by its pressure that which is before it until it reaches the sea. [AMAZONAS, in GEOG. DIV.] The surface of the Elbe at Hamburg, about 70 miles from the North Sea, is not more than 6 feet above the sea, and the fall per mile very little exceeds an inch. The surface of the plain through which a river runs generally consists of an alluvium, which the river has deposited during the inundations. The matter of which this alluvium consists is soft and loosely bound together, and consequently the current, slow as it is, has power enough to remove a portion of the banks from one side, and to deposit the detached matter on the other. Thus great changes are produced in the courses of rivers in the lapse of time. Major Rennell surveyed a large portion of the lower course of the Ganges, and his maps were very exact at the time. He also observed the changes which the river had produced in its bed. About fifty years afterwards the course of the Ganges was again surveyed, for the purpose of establishing a steam navigation, and it was found that the course of the river hardly in any place agreed with the maps of Rennell. The most remarkable circumstance however is, that a river frequently divides into a number of arms, each of which runs to the sea, though some branches re-unite and again detach themselves from one another. Thus the Danube reaches the sea by seven arms, as the Nile formerly did, according to the ancient accounts, though there are now only five arms in the Nile. Our best maps represent the number of the mouths of the Ganges as amounting to ten at least. This division of a river into several arms is easily understood when the soft nature of the alluvium is considered: and if we suppose that the river in its operation of changing its bed, finds in its way a piece of rock or other matter harder than the alluvial soil, by setting against such an obstacle the current is divided, and flows on both sides of it: the following inundation removes still more of the alluvium, and thus, in course of time, a new arm is formed.

The country which is enclosed by the arms of a river is called its *delta*, from the form of the Greek letter Δ, which the delta of the Nile, that which was best known to the ancients, greatly resembles: but the term is generally appropriate, as most river deltas have that form. To the base of the triangle, however, the deposit of matter brought down by the river adds a curved projection seaward, rendering the entire form of what is called the delta that of the sector of a circle. It is a common conjecture that the space which is now occupied by the delta of a river was once a part of the sea, which was filled up by the débris and earthy matter brought down by the river from the mountainous and hilly country through which its upper and middle course lie. This supposition is strongly supported by the nature of the soil, which evidently consists of matter brought down by rivers, and not of such as the sea leaves behind when, from any cause, it retires. (On this subject see Captain Spratt's 'Investigation of the Delta of the Nile,' as referred to in the article QUICKSANDS.) It may be added, that this operation of rivers goes on during the inundations, for after the waters have subsided the surface of a delta is found to be covered with a very thin layer of mud, which soon becomes dry earth. The deltas of rivers which are annually swollen by rains, which is the case between the tropics, are generally much more extensive than those which are formed by rivers whose inundations are only produced by the melting of snow.

There is a river of first-rate magnitude which has no delta, though it seems to possess all those qualities which are supposed to be requisite to the formation of such an alluvial tract: the St. Lawrence in North America reaches the sea by a kind of bay, which extends upward of 300 miles, and gradually increases in width from three to above one hundred miles. One would suppose that the form of this bay would render it subject to be easily filled up by the earthy matter brought down by a river whose course exceeds 1800 miles; and yet we do not find that an alluvium of any extent has been formed along the banks of this wide æstuary, except on the right bank below Quebec. This single instance might throw some doubt on the opinion that deltas are formed by rivers in the way above mentioned, if the peculiar nature of the St. Lawrence did not suggest an explanation of this deviation from the common course of things, which rather confirms than refutes the established principle. The St. Lawrence is the only large river which traverses a great number of lakes. Even after having left the five great Canadian lakes, it passes through those of St. Francis, St. Louis, and St. Peter. In each of these lakes the current ceases, and it is only perceptible where the river again issues from the lake. All the earthy matter therefore which the river collects and keeps suspended in its course from one lake to the other is deposited in these lakes. Thus this large river brings no débris and earthy matter, or very little, to its wide æstuary, which cannot therefore be changed into a delta by the accumulation of such matter.

Most large rivers, as already observed, admit of this division of their course into three parts, an upper, middle, and lower course; but the exceptions are far from being rare. It sometimes happens that the characteristic features by which the middle course is distinguished, occur in the upper course. This takes place when a river originates on an elevated table-land, and traverses a considerable part of it. Thus the Indus, the Sutlej (an affluent of the Indus), and the Sampoo, rise on the elevated table-land of Tibet, and drain a portion of it: in this part of their course they resemble the middle course of the Rhine or Danube. But where they leave the plain and enter the mountain-region of the Himalaya, they resemble the mountain-streams of the Alps, except as to the volume of water. When the Indus and the Sutlej have descended into the plains of the Punjab, they assume the character of the lower Rhine and lower Danube. The Sampoo, after leaving the mountain-region, traverses a hilly tract of great extent, the valley of Asam, before it enters the alluvial plain of Bengal. There are other rivers, in which only the characteristic features of the middle and lower course can be recognised: the number of such is considerable, and some of them are of the first magnitude. Thus the Volga and Mississippi, neither of which rises in a mountain-region, but in a hilly tract, in the greater part of their course present the characteristics of the middle course of the Rhine and Danube, but towards their mouths they traverse a large plain. The number of rivers whose whole course lies through a hilly or undulating country is still greater, as is the case with nearly all the rivers of England and Southern Scotland. There are also rivers which in their whole course traverse a mountain region, but they are all small; such are some of the rivers in North Scotland and in Sweden, and nearly all the rivers of Norway, and those on the west coast of South America.

The number of rivers which do not reach the ocean is not great, if we except those which fall into the Caspian Sea and into the lake of Aral. The other rivers without an outlet always terminate their course in a lake. It was formerly supposed that the water of some of them was absorbed by a dry soil, and that they were lost in the sand; and this opinion still prevails as to some rivers which descend from Mount Atlas southward to the Sahara. But the point remains doubtful. Among other rivers which have no communication with the sea, some few traverse elevated table-lands, consisting of plains surrounded by continuous mountain-ranges, through which the waters cannot find an outlet, and consequently collect in the lower part of the plains, and form lakes large enough to part with all their surplus water by evaporation. Such rivers occur in the valley of Tenochtitlan in Mexico. The most remarkable is the Desaguadero, in the valley of Titicaca in Bolivia, which runs about 300 miles, and is lost in a lake or in swamps. The Hyarkan or Yerkan, in Chinese Turkestan, is still larger, but its character is imperfectly known. Another kind of such lakes occurs in the plains of Mexico and of South America, and almost exclusively in those parts which have no rain or very little. On the table-land of Mexico the greater number of rivers between 24° and 30° N. lat. terminate in lakes; and in the states which compose the Argentine Republic, rivers of this kind are numerous between 28° and 34° S. lat., west of 64° W. long. As very little rain falls in some of these countries and in others none at all, the rivers are supplied with water by the rains which fall at certain seasons on the mountains in which they originate, and by the springs which exist there. But as the supply of water is very moderate, it does not give force sufficient to the currents to carry them through those extensive tracts which separate them from the sea. It is remarkable that some of these rivers and all the lakes in which they terminate, are salt in South America; and it is probable that this is also the case with most of those on the Mexican isthmus.

Most rivers overflow the low countries which are adjacent to their banks, either at regular seasons of the year or occasionally. This takes place when the supply of water is greater than the bed of the river can contain. In this respect rivers may be divided into three classes: the first comprehends the rivers whose inundations are produced by the melting of snow and ice; the second comprehends those which are annually swollen by regular rains; and the third those which only occasionally cause inundations.

All large rivers that drain countries of which the mean winter temperature is below 30°, are annually subject to great risings when the snow and ice melt. In such countries snow falls for several months, and as only a small part of it is dissolved, it accumulates to a great amount. As soon as the frost ceases, the snow begins to melt, and runs off by the smaller rivers, which suddenly swell and carry an unusual supply of water to the principal river, whose volume being thus increased to three or four times its ordinary magnitude, overflows the adjacent low country. These inundations, though they generally improve the soil, are very injurious to agriculture, by destroying the growing corn, and covering extensive tracts with sand, gravel, and other coarse earthy matter. In some rivers these inundations last only from two to four weeks; in others two or three months; and in some even five or six months. Where the inundations are long, they are less violent, and cause less damage than when they are short; in the latter case the whole mass of water suddenly deluges the country, while in the former the water rises slowly. This difference in the inundations of rivers is mainly to be attributed to the direction in which they flow. Let us take a river like the Mississippi, which flows from north to south through 17° or 18° of latitude. In winter the basin is covered with snow, and if the whole were melted in a few days, it would produce such a volume of water as would probably cover nearly half the basin. But the melting of the snow is gradual. Whilst the temperature in the northern districts is below the freezing-point, the spring has already made considerable progress in the southern districts, the snow which has there fallen has been dissolved, and the water thus produced has had the requisite time to run off and reach the sea. Thus with the progress of the sun towards the northern tropic, the line of the melting snow proceeds northward, and thus the supply of water runs off gradually, until the snow of the most northern region is dissolved. More than two months elapse between the melting of the snow in the northern region and the commencement of the melting in the lower part of the river. The inundations of the Mississippi therefore are not extensive, if the great length of that river and of its affluents be considered, but they last from three to four months. A considerable part of the delta of that river is indeed under water for six months, but this must be ascribed to the tract of elevated ground which extends not far from the sea between the Atchafalaya and the La Fourche, and prevents the enormous mass of water which collects in the lowlands near the first-mentioned branch from running off sooner. When a river situated in the northern hemisphere flows from south to north, the melting of the snow of course commences near the upper branches of the river, and proceeds northward. In this case the volume of water which collects at a certain period in the lower course, where the lowlands are generally most extensive, is much greater, and the inundations are much more extensive and attended with more mischief. But still they cannot be compared with inundations of those rivers which run from east to west or from west to east. In countries which are drained by such rivers, the whole mass of snow is dissolved in a few days, especially when a thaw is accompanied by rain, and all the waters thus produced pass through the principal channel in the course of a week or two. In such rivers the volume of water during the inundations is three or four times larger than it is in the middle of the summer or the beginning of autumn, and the inundations spread to a great distance, and frequently cause great loss of property, and sometimes also of life, especially when the winter has been unusually long and the falls of snow very heavy. [NIEMEN, in GEOG. DIV.] But the river St. Lawrence forms an exception here also. As its general course is from west to east, one would suppose that a large extent of country within its basin would be annually subject to inundation, but this does not appear to be the case in any part of its course. If any portion of it is swollen by the melting of the snow within the basin, the river soon enters one of the lakes through which its course lies, and thus the addition of a comparatively small volume is not sufficient to raise the surface of the lake to any large amount. Thus the same cause which prevents its filling up the wide æstuary, prevents the river from overflowing the adjacent country. A diurnal rise and fall characterises the rivers of Switzerland and those of the western Himalaya, where a powerful sun melts the glaciers by day, and the head-streams are frozen by night.

Rivers whose inundations are produced by regular rains have the greater part of their course either within the tropics or at least between 30° N. lat. and 30° S. lat. It is a known fact, that in those regions heavy rain falls daily from three to six months in the year. These heavy rains commence when the sun in its progress from one tropic to the other approaches the zenith of a country, and they continue till it has passed a certain distance from it. In the beginning of the wet season, as this part of the year is called in those countries, the rains are sometimes so heavy that in the course of a day the level country is covered with water a foot deep. The rivers of course soon begin to increase in their volume of water, and after some time they rise to the level of the banks, and begin to run over. These inundations generally last from two to four months. They are more regular than those which are produced by the melting of the snow, and in general do not exceed a certain height. The rural economy of those countries in which they take place is founded on the knowledge of this periodical event, and on the certainty that the inundations will fertilise the fields by depositing on them a fine mud, which enriches the soil more than the best manure artificially collected and applied. The supply of fertilising matter may not be due in an equal ratio to all the head-streams or all the tributaries of a river. In the important case of the Nile, according to M. Linant, an eminent scientific traveller and geographer, it is by the Atbara, its first great tributary, that most of the black-earth and slime is brought down which manures the lands in Egypt; from which it has received also the designation of Bahr-el-Aswad, or the Black River. Whenever the inundations do not rise to the usual height, which is sometimes the case, a great part of the country which is not covered with water yields little or nothing, and the consequence is dearth and famine. When, on the other hand, the inundations rise higher than usual, they are also injurious to rural economy, by reaching those tracts which are set apart for the cultivation of plants, which cannot bear so much moisture as the districts that are regularly flooded. Thus, in 1831, the river Menam in Siam rose to an extraordinary height: the inundations reached the large orchards which for many miles in extent cover the more elevated tracts along the banks, and afford subsistence to a numerous population. Several kinds of fruit-trees were almost destroyed, and for some years the mangusteens and durians were scarce.

The Indus [HINDUSTAN, in GEOG. DIV.] belongs to both of these classes of rivers, or rather to all three. The elevation of its waters is owing to the periodical melting of the snow and the subsequent rains, and it is subject also to enormous occasional inundations. In the year 1841, according to Major Cunningham, in his work on Ladak, the mass of water accumulated, and which caused the inundation of the lands bordering the lower part of its course, was estimated at 20,000,000,000 cubic feet, equal to a volume 100 feet deep, 380 feet wide, and 100 *miles* long. A similar inundation, though probably of inferior magnitude, took place in August, 1858, when, at Attock, the water rose 50 feet in seven hours and a half, and attained 90 feet during the day. Its affluent, the Cabul river, *flowed upwards* for ten hours. Valuable investigations of the mechanical philosophy of these phenomena, and of the relations between the velocity of a river-stream and that of the tide—or other waves to which it may be subject, by Mr. J. Obbard and Archdeacon J. H. Pratt, will be found in the 'Journal of the Asiatic Society of Bengal,' N. S., vol. xxix. (1860, No. iii.), p. 263–282. The latter subject has important relations with that of the ascent of the tide up a river, noticed below.

All the rivers between the tropics which are swollen by periodical rains lie only in one hemisphere, the northern or the southern. In the countries through which they flow the waters are low and the ground dry during part of the year, so as to admit of easy cultivation, and at another season the fields are fertilised by the inundations. The Nile and the Amazonas are alone exceptions. Though the course of the latter river is in the southern hemisphere, its affluents extend far to the north and south, into both hemispheres, and probably three-fourths of the tropical rains which descend upon South America find their way to that large river. To this circumstance are owing its immense volume of water and its great depth. The Amazonas, properly speaking, is never at its lowest level, in the sense in which that term is applied to other rivers. When the northern rivers cease to bring down the supply which is owing to the periodical rains, the southern begin to bring their contributions. This fact seems sufficiently to explain the immense tracts of alluvial soil which extend along the river to a great distance, but the same circumstance also keeps the soil in a state of continual moisture, and makes it a perpetual swamp. Accordingly we find that the banks of that river, which admits of a more extensive navigation than any other river in the world, remain nearly destitute of agricultural settlements, and are still in the possession of savage tribes. In the northern portion of the upper course of the Nile, that river appears to be almost stagnant except during the rains, and to consist in the dry season of a series of swamps and lakes, rather than to form a continuous stream.

The rivers which drain the countries between 30° N. latitude and those in which the mean temperature of the winter season does not rise above 30°, are subject to occasional inundations. But these overflowings occur only in those rivers whose upper course lies within mountain ranges which are covered with snow for a considerable part of the year. In such cases, while the snow covers the more elevated portion of the mountain-ranges, a sudden change in the weather, which produces a warm wind, brings great volumes of vapours, which, falling in abundant rain, soon dissolve the snow, and the mountain-streams pour down their waters with increased volume and velocity. As soon as the waters reach a level tract, it is inundated. As these inundations often take place unexpectedly, they cause great damage. Thus we find that some valleys in the Ozark Mountains, in the United States of North America, are almost uninhabitable, owing to the sudden inundations to which the rivers of that mountain-region are subject. Many rivers however never inundate the adjacent country, unless a heavy gale of wind should blow directly up the river, and drive the sea into it with great force. Such inundations are very sudden, and sometimes also extensive, but they are of short duration. [CLIMATE: RAIN.]

An important subject in the history of rivers, relating to the distribution of temperature within certain areas of the earth's surface and the immediately incumbent atmosphere, and their equalisation in others, and which bears also on the connection of rivers with the welfare of organic nature and the human race, is the variation of their temperature in different parts of their course, both at the same and at different seasons. This depends, proximately, on the temperature of their affluents, and may even give information of the physical state of the countries in which they rise, when these are otherwise unknown. Dr. Joseph D. Hooker, in his 'Himalayan Journals' (vol. ii., p. 60), has given some interesting facts on this point, as presented by the rivers which rise in the Sikkim Himalaya. The Teesta, a tributary of the Megna, or Brahmaputra, is always cool in summer (where its bed is below 2000 feet in absolute elevation), its temperature being 20° below that of the air; whereas, in mid-winter, when there is less cloud and the snows are not melting, it is only a few degrees colder than the air. At Bhoomsong, of which the elevation is 1500 feet, the mean temperature of the Teesta, in that season, was 51°, and that of the air 52°·3; at that elevation the temperature of the water rarely exceeds 60° at midsummer. Between the altitudes of 4000 feet and 300 (the plains of India) its mean temperature varies about 10° between January and July; at 6000 feet it varies from 55° to 43° during the same period; and at 10,000 feet it freezes at the edges in winter, and rises to 50° in July. In June, in descending from 12,000 to 1000 feet, Dr. Hooker found that its temperature did not rise 10°, while that of the air rose 30° or 40°. The temperature of the northern feeders of this river, in some parts of their course, actually rises with the increasing elevation. Thus, the Zemu, during the traveller's stay at its junction with the Thlonok (which has its source in the north-east snowy flank of Kinchinjunga, one of the three or four highest mountains in the world), was at 46°, or 6° warmer than the latter; at 1100 feet higher it was 48°, and at 1100 feet higher still it was 49°. "These observations," Dr. Hooker adds, "were repeated in different weeks, and several times on the same day, both in ascending and descending, and always with the same result: they told, as certainly as if I had followed the river to its source, that it rose in a drier and comparatively sunny climate, and flowed among little snowed mountains." Another explorer of nature, Mr. Alfred R. Wallace, has recorded ('Travels on the Amazon and Rio Negro,' p. 431) some facts apparently of the same description, not, however, observed by himself, and which he professes his inability to account for. In the month of May some very cold days are said to occur annually on the Upper Amazon and Rio Negro, sometimes so severe that the inhabitants suffer much, and the fishes in the rivers even die of the cold; though five or ten degrees of diminution of temperature, Mr. Wallace remarks, is as much as ever takes place. We conceive the depression of temperature of the local atmosphere affecting the inhabitants to be occasioned by the air brought down in contact with the cooled water of the rivers, the temperature of which must be still lower, and that the cause is the annual melting of the snows about the sources of some of their head-streams.

In adverting to the advantages which a country derives from its rivers, we must first observe that the water is extensively used for the purposes of domestic economy. It is much purer than that of wells; for river water in general contains much less saline matter than spring-water; it has also earthy particles in suspension, which may easily be separated by filtration, and which are deposited as a sediment when the water is left to stand for a short time. The water of wells generally contains a small quantity of some mineral salts in solution. The water of rivers is used, and is nearly equal to rain water, for all domestic purposes. The upper courses of rivers are generally inhabited by a small number of species of fish, and the whole amount is not great. But towards their mouths the number both of species and individuals increases. The importance of a river fishery may be estimated when we consider the quantity of salmon which is taken in the rivers of Britain, or of the beluga and sturgeon which is caught in the neighbourhood of Astrakhan. Many rivers, which are not adapted to the purposes of navigation, are converted into powerful instruments for assisting the industry of a country by the moving-power which they supply for mills and other heavy machinery. The advantage of such a natural moving-power primarily determines the seat of manufactures, as was the case in South Lancashire, where this advantage is combined with abundance of coal. The Atlantic States of North America are generally provided with abundance of streams, a circumstance which favours the establishment of manufactures.

The greatest advantages however which a country derives from its rivers are the facilities which they supply for conveying the produce of agriculture and of manufacturing industry to distant parts at a moderate expense. In this respect the rivers may be compared to the arteries and veins of the human body, which diffuse life and strength through all parts. Navigable rivers vivify, maintain, and excite the efforts of human industry. In many countries, where roads are neglected, it is estimated that the transport of goods by land is four times as expensive as that by means of navigable rivers, and thus many heavy and bulky commodities could not be brought to market but for the cheap conveyance of rivers. In considering the capacity of a river for navigation, two circumstances mainly require notice—how far seafaring vessels may ascend, and how far the river is navigable for river boats.

Seafaring vessels can ascend many rivers as far as the tides extend. Indeed some rivers, as the Amazonas, may be navigated by large vessels to a much greater distance than the tide ascends, but in others the waters become shallow long before the limit of tide-water is reached. Still high tides facilitate the navigation of rivers by large vessels, not only by producing a current contrary to that of the river, but also by temporarily increasing the depth of water so that vessels can pass over shallows and sandbanks, which at low tides are nearly or quite dry. This is frequently the case in rivers where the tides rise more than 12 feet. The tides in rivers are not of equal duration, as is the case in most parts of the sea; but the ebb tides frequently last twice as long as the flowing tides. At Rotterdam the tides flow for about 4 hours and 5 minutes, but the ebb lasts 7 hours and 55 minutes. The Meerwede at Dordrecht flows against the current of the river for 3 hours and 51 minutes, and with it 8 hours and 9 minutes. This difference is easily explained, when the force of the river current is taken into account. The same circumstance explains the difference in the velocity of the ebbing and flowing tide. Between the North Sea and

Hamburg, the flowing tide takes 5 minutes to run up a mile, but the ebb tide performs the same distance in less than 4 minutes. But it is difficult to explain the well-established fact that the tides advance much farther into a river than might be expected. When the tide at the mouth of a river rises 4 feet, we might suppose that it would advance only to such a point in the river, where the surface is 4 feet above the sea, but it has been ascertained that it advances further. It seems that the volume of water which is carried up by the tide is pushed onwards by the mass behind it, and carried to a greater distance than the inclination of the river bed would seem to allow. It has also been observed, that during the flowing of the tide the surface of the water in the river presents a somewhat convex form, the water along the banks being a little lower than in the middle of the river, and that during the ebb the contrary takes place. The flowing tide raises the water from below, and thus sooner affects the main body of the river, where it has more room to operate, than the water near the margin. In accordance with this explanation it is observed that the flowing tide is perceptible in the middle, while it is still ebbing along the banks, and that vessels which are at anchor near the banks are turned round before the water on the surface of the river near the banks begins to flow upward.

In a few rivers the tide ascends to a great distance from the sea. In the Amazonas it is perceptible in the Narrow of Pauxis near Obydes, a distance of nearly 500 miles from the mouth of the river, measured along its course. If we suppose that the tide in this river advances at the rate at which it runs in the Elbe between the North Sea and Hamburg,—namely, nearly a mile in five minutes,—the tide can only reach the Narrow of Pauxis in 42 hours, or in a space of time during which the direction of the tides has changed seven times at its mouth. It is therefore evident that the current of the Amazonas between the sea and the Narrow of Pauxis must, at the same time, in three or four different parts of its course, follow the impulse given to it by the tide, and run against the stream. We are of opinion, however, that the tide in the Amazonas advances more slowly than in the Elbe, owing to the stronger current of the Amazonas, and that the number of high tides in the Amazonas, between the two above-mentioned points, will probably be found to be five or six. The tide rushes into some rivers with great impetuosity, and produces what is called a *bore*. [BORE; WAVE.]

Human ingenuity, even in the lowest state of civilisation, has perceived the use of rivers as means of conveyance. Perhaps all rivers which have water enough to carry the smallest boats of any shape or form are navigated, except where the nature of the current opposes insuperable obstacles. These obstacles consist of *cataracts* or of *rapids*. When the river descends from a rock which rises several feet perpendicularly, it rushes down in a broken sheet of water, and is said to form a cataract. When the water descends with great velocity over an inclined plane of rock, it is said to form a rapid. A cataract may be descended when it is only a few feet high. Rapids may be ascended and descended in most cases with great labour and some danger, when they are not very long, and the bed of the river is free from projecting rocks, which however is rarely the case. The ascent of rapids is effected either by poling or by dragging the boats over the dangerous place by means of long ropes. Sometimes ropes are also used in the descent, as in the Rhine at Laufenburg in Switzerland. But generally either the whole cargo or a part of it must be taken out of the boat, and carried a certain distance by land. Such a tract, over which the goods must be carried, is called a *portage*. At long and dangerous rapids the boats themselves must be carried or dragged over the portages.

River boats differ greatly in shape and construction, being always adapted to the nature of each river. Most rivers contain numerous shoals, on which the water is very shallow, and accordingly flat-bottomed boats are used, like the coal-barges in London. Keel boats can only be used where the river has a depth of a few feet, and is free from shoals and sand-banks. When a river is shallow and rapid, but of considerable width, rafts are substituted for boats. Rafts generally consist of trees fastened together with ropes or the flexible branches of trees, or, in warm countries, by creeping plants; goods are placed upon the raft. When these rafts, with their cargoes, have arrived at their place of destination, the raft itself is sold, either as timber or as firewood, according to its dimensions and quality, and the crews return by land. When a river is too full of cataracts and rapids to allow either boats or rafts to descend, it may still be used for floating down timber or firewood. The trunks of trees, after being deprived of their branches, are thrown singly into the current, and towards the mouth chains are laid across the river, above which the trunks collect, and whence they are carried to their destination. This is frequently done in the rivers of the southern districts of Norway.

Rivers which traverse a mountain-region in some parts of their course are either not navigable in this part or only in some places. Thus the Amazonas and Ganges, where they respectively flow within the ranges of the Andes and Himalaya Mountains, are not navigable; but the Rhine and the Danube are navigable even within the mountains, in some parts for a considerable distance. The most extensive system of internal navigation is presented by those rivers which have a long course, and whose sources are situated at a comparatively small elevation above the sea. The Volga is navigable in the whole length of its course, and the Mississippi up to the Falls of St. Anthony, a distance of about 1800 miles, measured along the river. Both these rivers, as already observed, have the greater part of their course between hills of small elevation, and they do not traverse a mountain-region.

The rivers of England supply the means of an extensive system of inland navigation—a circumstance partly due to their small fall, their sources being only a few hundred feet higher than their mouths, and partly to the abundant supply of water from rain, mists, and springs. Accordingly, if two rivulets unite, they generally form a small navigable river, and such as are not navigable become useful as feeders to canals. The navigation of most of the rivers of England has been much improved by artificial means.

The Thames is navigable for large sea-vessels to London Bridge, a distance of 45 miles from the Nore, though the whole course of the river, measured along its windings, hardly exceeds 200 miles. No river in the world, perhaps the Amazonas excepted, is navigable for vessels of such dimensions for one-fourth of its course. This circumstance is not due solely to the height of the tides, which is about 19 feet at London Bridge, but mainly to the fact that there are no sand-banks at its mouth which prevent the access of large vessels. The river probably brings down sufficient earthy matter to form a bar but owing to the direction of the tide, which is kept off from the mouth of the river by the projecting coast of Kent between the two Forelands, and there being consequently nothing to oppose the current of the river at its mouth, the earthy matter is carried farther from the coast, and deposited in deep water.

The advantages hitherto enumerated are common to rivers in all parts of the globe; but there are some countries in which the value of rivers is much increased by the use which is made of the water for irrigation. This occurs in those countries in which it either does not rain at all, or in which rain occurs only at a certain period of the year, and even then only for two or three months. The first class of such countries—for instance, the western coast of South America, between 5° and 28° S. lat., would be uninhabitable but for the rivers which descend from the western declivity of the Andes, and in their course to the sea have furrowed the surface with deep depressions or valleys, in which agriculture is carried on with success as far as the water of the river can be dispersed over the level part of the valleys by small canals. In those warm climates where the rains occur periodically, though only in two or three months of the year, the fields would certainly produce a crop, even without irrigation; but for more than half the year the soil would produce nothing for want of water. By using the water of the rivers for irrigating their lands, the inhabitants of those countries are enabled to get two, and in many cases three, crops annually. Even in the southern countries of Europe, where rain is very scarce in summer, and not sufficient to maintain vegetation, whilst the heat is excessive, irrigation is practised, and two crops of Indian corn are thus annually obtained, or one crop of wheat and a green crop.

In those countries in which the temperature for three or four months is under the freezing-point, the rivers during that time are covered with ice, and in this state they afford to the inhabitants, in some degree, the advantages which other countries derive from railways. Travelling and the transport of goods on the smooth ice of the rivers are much less expensive, and are performed in a shorter time than in summer in the ordinary way. This is the case on some of the rivers of New Brunswick and Lower Canada.

It has been observed, that the outer borders of river-basins are the most elevated parts which occur in some given places between their respective beds, though it is not always the case that the water-parting is formed by mountain-ridges. Owing to such a disposition of the surface, the waters which are collected on or near the borders run to one or the other of the two rivers. Up to the commencement of this century it was thought improbable, if not impossible, that two different river systems or basins could be united by a natural water communication; but it is now ascertained that a low tract of country or a deep depression of the surface may occur, by which a portion of the water of a river, after being diverted from its own channel, may join a river which otherwise is not connected with that river from which the water branches off. The instances in which this occurs are very few, and we shall therefore enumerate those whose existence is beyond all doubt. The river Arno, in Tuscany, in that part where it runs between the high ridges of the Apennines and approaches the town of Arezzo, sends an arm southwards through a narrow valley, under the name of Chiana, which falls into the Chiare, an affluent of the Tiber. The Chiana had been filled with sand, but its course has been re-established by artificial means. Another case occurs in the kingdom of Hanover, a few miles east of the town of Osnabrück, where the river Haase divides into two branches, of which one, running west to Osnabrück, preserves its name, and, after a course of many miles, joins the Ems; the other, running east under the name of Elz, falls, after a short course, into the Werre, an affluent of the Weser. In Sweden, two large rivers fall into the northern extremity of the Gulf of Bothnia—the Tornea Elf and the Calix Elf. About 100 miles from the sea, the last-mentioned river sends off an arm to the south-east, which, after a course of about twelve or fifteen miles, falls into the Tornea Elf: this arm is called Tarenda Elf. In these cases the rivers thus united by a natural water communication flow in the same direction, or nearly so. But in South America, two large rivers, the Orinoco and the Amazonas, are united in this way in a part of their extensive courses, where the Orinoco runs west and the Amazonas east. The branch of the Orinoco by which this natural water communication is effected is called the Cassiquiare. [Orinoco, in Geog. Div.] This phenomenon is otherwise described as the *bifurcation* of a river high up its course, of which the Mareb, one of the tributaries of the Nile, already mentioned, affords another example.

It is a kind of established rule, that the whole course of a river should bear the same name, and that this name should be continued to that branch or head-stream whose sources are farthest from the mouth. But practice is frequently at variance with this rule, and in a manner establishes another. The inhabitants of a country preserve the name of that river which does not undergo any deflection of its course. At the confluence of the Mississippi and the Missouri, the latter is the larger river, and has had a course of above 1000 miles more than the former, but it does not deflect the course of the Mississippi by its junction, and the name of the last-mentioned river is preserved. The same occurs in South America as to the Amazonas and Madeira, where we find that the last-mentioned river changes the direction of its course to meet the Amazonas, whose name is preserved. In Europe, the Rhine is joined by the Aar in Switzerland, above Laufenburg. The Aar is the larger river, and brings down a greater volume of water; but the Rhine, where it is joined by it, continues its westerly course, and its name is preserved. There are also two rules for determining which of the various head-streams of a river is entitled to be regarded as its upper course, and consequently to bear the name borne by the united stream lower down: the one rule is at the same time theoretical and natural; the other is practical or conventional. By the former, the greater length and size, and the general direction of the valley or basin of the river, are the main considerations. By the latter, it is the first acquaintance which the inhabitants or discoverers of the valley of the main stream may make with one of its branches (or the converse) that causes the name of the former to be extended to the latter.

The extent of a few river basins is here given in round numbers, but they must only be considered as rough approximations:—

Rivers.	Square Miles.
Thames	6,500
Atbara, the fertilising tributary of the Nile	60,000
Rhine	89,000
Euphrates, including the Tigris	108,000
Brahmaputra	270,000
Danube	312,500
Indus	410,000
Ganges	443,000
Volga	653,000
Nile	707,500
Yan-tse-kiang	742,000
Mississippi	1,100,000
Plata	1,200,000
Oby	2,000,000
Amazonas	2,330,000

According to Humboldt the area of drainage of the Amazonas measures 3,000,000 of square miles; but in this he, in all probability, includes that of the Tocantins [Brazil, in Geog. Div.] which Mr. Wallace, correctly in our opinion, regards as a distinct river.

RIVETING, considered in its simplest form, is nothing more than the hammering of an iron bolt through a hole punched in two iron plates; but in the vast engineering operations of the present day, where rivets are used, not merely by the thousand, but by the million, the rapid and exact management of the operation become important matters. The Britannia tubular bridge over the Menai was the first of these great examples of rivet-fastened plates; the *Great Eastern* steamship was a second; and the Victoria railway bridge over the St. Lawrence, at Montreal, is a third. The rivets themselves may be simply pieces cut off from iron rods, and heated in a forge to a state fit for hammering; but under Nail Manufacture will be found a notice of certain machines which are equally suited for making nails, rivets, nuts, and spikes.

At a meeting of the Institute of Mechanical Engineers, in 1857, Mr. Harvey made the following observations on rivets and riveting:—"In the manufacture of steam-boilers, the operation of riveting is mostly effected by hand-labour; and in order to bring the heads of the rivets to a proper form and finish, much of the hammering takes place when the rivet has approached to a nearly cold state. The tendency of this is, to destroy, to a certain extent, the fibrous character of the rivet. The case of a rivet-head, starting off under the operation of proving the boiler, although seldom occurring, has revealed the fact that a crystalline character must be more or less assumed by the iron in all rivets worked in the usual manner; and hence, besides ariving at economy by the use of steam for riveting, it is very desirable that the rivets should be finished in as short a time as possible, and without that succession of blows by which the fibrous character of iron is always more or less injured." In hand-riveting, it may be added, the head is made conical by the shape and action of the riveting hammer; whereas in steam-riveting the head becomes convex, which is better. Nevertheless, steam-riveting machines, though many have been invented, have not hitherto come much into use. Some are found to be too complex, and likely to get out of order. Some require a pressure of steam of 50 lbs. on the square inch, with either a separate boiler or a large steam-cylinder, which renders them too costly. Some have a defect arising from the peculiar mode in which they act; a cam, moving through a fixed distance, and acting through a combination of levers, with a fixed distance for the travel of the riveting die, is unable to adapt itself to irregularities in the lengths of rivets which may occur in general work, and which *must* occur when rivets go sometimes through two, and at other times through three thicknesses of plates. Messrs. Whitelaw and Harvey have endeavoured to surmount some of these difficulties in a riveting-machine of recent introduction. The steam-cylinder is 15 inches in diameter by 24 inches stroke. A system of levers and eccentrics carry a shearer, a punch, and a die; for the machine is intended to perform all three operations of cutting iron plates, punching holes in them, and then driving rivets into the holes. The machine is not wholly self-acting; it is momentarily stopped by hand after every stroke. The effective action of steam is upwards; the downward movement is the effect of the weight of the moveable parts of the apparatus. Between the piston and the bottom of the cylinder a portion of the exhausted steam is retained as a cushion, to bring the piston softly to rest. Steam of 20lb. to the inch has pressure enough for this machine. It has power to punch a hole three-quarters of an inch diameter through a cold iron plate three-quarters of an inch thick, and to effect the cutting and the riveting for the same plate. In riveting, the action upon the rivet-head is a *pressure*, not a blow; this pressure becomes more and more intense as the process advances, until just before the head of the rivet is finally shaped, it amounts to something like 30 tons.

In riveting, whether by hand or by machine, it is necessary to furnish a pressure against one end of the rivet to assist the action at the other. In the hand method, one man holds a hammer forcibly against one end of the rivet in the hole, while another strikes the other end. In the machine method, the action is like the pressure of a die and counterdie.

RIVULIN. A mucilaginous matter found in a species of fresh-water plant, the *Rivula tubulosa*.

ROAD. Under this head it is proposed to embrace road-making, with a brief sketch of the history of roads, referring for more detailed statistical information to the Geographical Division of this work, and to Way and Turnpike Trusts for an explanation of the laws respecting the formation and maintenance of the highways in this country.

The importance attached to roads by the great nations of antiquity is abundantly testified by historians, though, except in the case of the Roman roads, there are few remains existing. The Carthaginians are said to have been the inventors of paved roads, which were much used by the Romans, who were distinguished by the vast extent and solid construction of their highways, of which several thousand miles were made in Italy alone, while every country which was brought under their sway was more or less intersected by these channels of communication. Though formed mainly to facilitate military movements, the Roman roads were productive of the greatest civil benefits. Being made by a power whose resources were almost unlimited, these military roads were usually laid out in straight lines from one station to another, with little regard to natural obstacles, which were frequently passed by means of very extensive works, as excavations, bridges, and in some instances, tunnels of considerable length. The solidity of their construction was fully equal to the boldness of their design; a fact proved by the existence of many that have borne the traffic of near two thousand years without material injury. The Roman engineers were very particular in securing a firm bottom, which was done when necessary by ramming the ground with small stones, fragments of brick, &c. On this carefully prepared foundation a pavement of large stones was firmly set in cement, the stones being occasionally squared, but more commonly of irregular shapes, though always accurately fitted to each other. For this purpose many varieties of stone were used, but the preference seems to have been given to basalt, where it could be had, it being used in many situations in which other suitable materials might have been procured with less labour and expense. Where large blocks could not be conveniently obtained, small stones of hard quality were sometimes cemented together with lime, forming a kind of concrete, of which masses extending to a depth of several feet are still in existence. The Roman roads were generally raised above the ordinary surface of the ground, and frequently had two carriage tracks separated by a raised footpath in the centre.

In some parts of the continent of Europe, especially in Italy, the Roman system of road-making has been imitated, particularly in city pavements; but in Britain the attempts to follow the Roman model appear to have been very limited, and road-making has been very imperfectly practised till within the last half century. Many of the existing highways were originally mere paths or tracks from place to place, their course having been determined more by accidental circumstances than by a due attention to the properties of a good road. Thus deviations were made from the direct course in order to cross rivers at fordable points, and the road was conducted over a hill in preference to a more level course round its base, to take advantage of natural drainage. As improvements have been introduced in the systems of construction and repair, the direction and levels have been frequently left unaltered, to avoid the temporary inconvenience and expense attending a deviation from the established course. The scanty information we possess as to the state of the roads in early times indicates that it was very bad; and after the introduction of turnpikes, and even down to the commencement of the present century, the greater part of the roads were, owing to injudicious modes of construction and repair, in a state very unfit for traffic.

The inefficiency of the system of maintenance by parish and statute labour was proved before the passing of the first Turnpike Act in 1653; yet the necessity of improvement, and the obvious justice of maintaining roads by the produce of tolls, did not lead to the extensive adoption of the turnpike system for about a century after that time.

During the last sixty years the attention of government has been repeatedly directed to the importance of this class of public works, and the Highland and Holyhead roads, formed by Telford and others, did much in improving and extending the science of road-making. The Highland roads alluded to were made under the commission of 1803, and originated in the military roads formed in consequence of the rebellions of 1715 and 1745, which had been found very beneficial to the districts to which they afforded the means of access. The roads made and improved under the management of the Highland road Commissioners extend to more than 900 miles, the whole being in a mountainous district, but so well laid out that their inclinations are always moderate. The works executed in the formation of these roads are very extensive, and comprise upwards of 1100 bridges. The Holyhead road improvements were commenced in 1815, and in these Telford and his able assistants had the opportunity of carrying into effect, under a government commission, a plan of road making suitable to a great traffic, on principles generally considered to be nearly perfect. The principles on which these important works were executed are very fully detailed by the late Lord Congleton, then Sir Henry Parnell, in his valuable 'Treatise on Roads,' to which work the writer of this article is indebted for much of the following information. The name of McAdam must not be passed over without notice in this place, as his exertions have done much towards attracting public attention to the improvement of roads, even where his peculiar principles have not been acted upon.

Though much remains to be accomplished, and the philosophy of road-making is yet very imperfectly understood by a large proportion of those to whom the care of the highways is committed, it is impossible to compare the past and present state of roads without feeling grateful for their improvement, and observing in how great a degree that improvement has benefited the agricultural, commercial, and moral interests of the community.

Designing a Line of Road; Earth-works, &c.—Though formerly little attended to, the design of the plan of a line of road is a subject which requires extensive knowledge and mature deliberation. It is often advisable to survey several different lines, in order to the selection of the one which, on careful comparison, appears to have the preponderance of desirable qualities. To be theoretically perfect, a road should combine the qualities of straightness and level, and its surface should be smooth and hard; and the best road, practically, will be that which makes the best compromise between unavoidable deviations from this theoretical perfection. It may be observed, however, that although some writers speak of the absolute perfection of each of these qualities as essential to the idea of a good road, it may be questioned whether it be desirable of any, excepting of the first. Of these qualifications the first two belong to the design or laying out of the line, and the last two to the execution of the road and the materials made use of.

The qualities of straightness and level, or the *line of direction* and *line of draught*, should be very carefully adjusted to each other. Some remarks on this subject will be found in the article Railway, which apply equally to the laying out of common roads, though the proportionate retardation due to a given ascent is very different, owing to the great comparative resistance of a common road. Among the circumstances that may authorise a deviation from the straight line, are the power of obtaining suitable materials for the road, avoiding valuable property or difficult ground, and including towns or villages in the route.

It seems to be a prevailing opinion with modern engineers, that the line of direction has not generally been made as subordinate as it should be to the line of draught; and it will be well to remember, in laying out a new road, that while the effect of gravity must ever remain the same, the resistance occasioned by imperfections in the road and carriages will be reduced by every prospective improvement in their construction; thereby increasing the *proportionate* effect of gravity, and making the line of direction still more subordinate to that of draught, or, in other words, increasing the length of level road that may be traversed with the same expenditure of power as would raise the load up a given elevation. Curves increase the resistance to the motion of carriages, and add to the risk of accident; but if slight, they increase the length of the road much less than might be supposed. Edgeworth, in his 'Essay on the Construction of Roads and Carriages,' says, "A road ten miles long, and perfectly straight, can scarcely be found anywhere; but if such a road could be found, and if it were curved, so as to prevent the eye from seeing farther than a quarter of a mile of it, in any one place, the whole road would not be lengthened more than one hundred and fifty yards."

The principle explained in the article Railway, of so arranging the inclinations on each side of the summit, or highest point unavoidably passed over, that there may be no unnecessary rise and fall, is equally deserving of attention in the design of a common road, although it has been much neglected. The following statement respecting an old road in the Isle of Anglesey, which was altered by Telford, shows how very much a road may be improved by judicious alterations; not only by shortening the line and lowering the summits, but also by diminishing the minor undulations:—

	Summit above high water.	Total rise and fall.	Length.	
			Miles.	Yards.
Old road . . .	339 feet	3,540 feet	24	428
New road . . .	193 ,,	2,257 ,,	21	1,596
Difference . . .	146 feet	1,283 feet	2	592

However desirable a perfect level may be in theory, a road with moderate inclinations, as of 1 in 100, is found to be preferable in practice, because without such a slope it is difficult to get rid of water fast enough, unless the road be raised a few feet above the surrounding land, and thereby exposed to the free action of sun and wind. Slight undulations are also considered, by most authors, to be desirable in all cases where animal power is employed; frequent changes in the nature of exertion being considered favourable to the horses. On this principle it is recommended that where an undulating road is reduced to a uniform gradient, occasional levels should be introduced to ease the draught. Any inclination exceeding the angle of repose, or that beyond which a carriage would roll down by its own gravity, occasions a loss of power; but all below it are attended with a compensating effect when the traffic in both directions is taken into account; the advantage gained by descending carriages being equal to the additional labour required in the ascent. This angle has been stated by Lardner to be about 1 in 40, with a good carriage on a broken stone road of the best quality; but the inclination allowed on the Holyhead road is 1 in 35, a slope which may be ascended at a good rate of speed, and descended at twelve miles an hour without risk. A greater slope not only occasions much additional resistance in the ascent, but, by rendering it unsafe to drive down at full speed, causes a loss of time in the descent also. Modern engineers consider it unadvisable in any case to exceed an inclination of 1 in 24, though there are hills at least twice as steep on some turnpike roads. The following table shows the effect of various inclinations in increasing the draught of a stage-coach at different velocities on the same description of road, as indicated by a dynamometer contrived by Mr. Macneill for experiments on the draught of carriages:—*

Inclination.	Force required at		
	6 m. p. hour.	8 m. p. hour.	10 m. p. hour.
1 in 20	268 lbs.	296 lbs.	318 lbs.
1 ,, 26	213 ,,	219 ,,	225 ,,
1 ,, 30	165 ,,	106 ,,	200 ,,
1 ,, 40	160 ,,	166 ,,	172 ,,
1 ,, 600	111 ,,	120 ,,	128 ,,

It should always be borne in mind that the occurrence of one steep hill on a line of road affects the working of the whole stage, as the number of horses required for ascending it must be used, although a portion of their power may be unemployed, on the greater part of the road. The inconvenience of a steep inclination may be diminished by laying a stone tramway for the use of ascending vehicles; a measure adopted with success on the Holyhead road, where, on a slope of about 1 in 20, the power required to draw a ton was reduced by this means from 294 lbs. to 132 lbs.

In arranging the works necessary for obtaining the required level, the preference should be given to embankments; and, wherever it is practicable, the bed of the road should be elevated two feet above the natural level, for the sake of efficient drainage. Tunnels are very rarely introduced on common roads, being very costly, and, when of considerable length, inconvenient from their darkness. When the road is in an excavation, the side-slopes should never be steeper than two horizontal to one vertical, and it is desirable to have those on the south side three to one; because, though many materials will stand at steeper inclinations, it is essential to the preservation of the road, and the comfort of horses travelling upon it, that the sun and air should have free access to its surface. Where stone can be readily procured, the erection of walls at the bottom of the slopes gives a neat and finished appearance to the road, and prevents earth, which may be loosened from the sides, from falling into the side channels or drains. The Highgate Archway road affords an example of the great difficulties that occasionally attend a deep excavation owing to the accumulation of water, the remedy for which is described hereafter. Where embankments are required, strong fencing is especially necessary to guard against the occurrence of accidents. Some of the roads formed by Telford are conducted across deep valleys by bridges or viaducts of great magnitude, in order to maintain the desired level without the inconvenience and expense of large earth embankments.

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* This useful instrument, which its ingenious inventor denominates a *Road Indicator*, is mounted on a light phaeton, and besides marking the draught at every ten or twenty yards, points out the distance run, and the rates of acclivity or declivity on every part of the road. A full description of it is given in Parnell's 'Treatise on Roads.'

In old roads the bridges erected for the passage of rivers are frequently made much smaller than is advisable, so that the level of the road is made too low, and the water is impeded by the contracted arches to such a degree as to occasion much damage during floods. Modern engineers, by adopting bolder dimensions for the bridges, and forming raised approaches, avoid these inconveniences, and secure their roads from the risk of obstruction by floods. The raising of the road wherever it passes through marshy or low land is a very necessary measure. Many old roads still in use are sunk several feet below the surface of the ground, because they have originally been exposed to the destructive action of water, and the materials thus softened have been ground into mud and cleared away, until, by the repetition of these operations, the roads have been converted into deep trenches, which are frequently flooded in winter. Of the extent to which this process has been occasionally suffered to go on, an idea may be formed from the statement of Edgeworth, that "the stag, the hounds, and the horsemen have been known to leap over a loaded waggon, in a hollow way, without any obstruction from the vehicle."

In conducting a road through a mountainous district, in addition to numerous bridges for the purpose of crossing ravines (for which purpose suspension bridges have been occasionally applied, as in the passage of the Menai strait), embankments between retaining walls of stone, and walls to support the road along the face of a precipice, are frequently necessary. Some works of the latter character have excited much admiration. If the slope of a precipice be only six inches horizontal to a foot vertical, such a road may be formed by building a wall thirty feet high, based on steps cut into the rock, and cutting into the rock to the depth of ten feet on a level with the top of the wall, the space between which and the face of the precipice is filled in with earth or stone. By this means a platform twenty-five feet wide is obtained. Many works of this character have been executed by Telford and other engineers, in various parts of Scotland, in the Highland roads, and those forming the communication between Edinburgh and London; and others, the boldness of which commands universal admiration, occur in the great mountain-passes of the Simplon and Mont Cenis, which form imperishable monuments of the talent and energy of the engineers of Napoleon, by whom they were executed.

When the works are completed to the proper level for receiving the hard materials that form the surface of the road, the earth should be formed into the intended width and a nearly level surface, the footpath or paths being elevated a few inches above the bed of the carriage-way. Thirty feet is the ordinary width of the carriage-way, exclusive of footpaths, of the Holyhead road; but the propriety of reducing the width, in most places to twenty-four or twenty-five feet, has been suggested. This width may be more or less exceeded in the vicinity of large towns, according to the amount of traffic, but should be exactly adhered to in other situations, as uniformity in this particular greatly improves the appearance of a road, and also contributes to economy, both as to the land and materials, and the cost of maintenance. Some engineers recommend that the bed should be made convex, in the same degree as the finished surface of the road; but it is quite flat in the Holyhead road, by which means a greater depth of materials is allowed in the centre than at the sides of the road. Much has been said on the subject of the best form for the transverse section of a road. Formerly it was common to make it very convex, often to a degree that was highly dangerous, with the idea of throwing off water; but this notion is very fallacious, because if a road be allowed to wear into ruts, no degree of convexity that can be given is sufficient to keep it dry; while, if the surface be good, a very moderate slope is sufficient to carry off water, and a steep inclination will cause it to run with such velocity as to wear away the road materials. Another disadvantage of too great an inclination is, that, by throwing the weight of a carriage on one side, the vehicle itself is injured, and the overloaded wheels cut up the road more than necessary. Some have gone so far in opposition to this practice as to advocate perfectly flat or even concave roads, in favour of both of which much may be said; but the general practice of modern road-makers is to make the surface slightly convex. In Telford's roads the convexity is elliptical, the fall being half an inch at four feet from the centre, two inches at nine feet, and six inches at fifteen feet. It has been recommended to form the cross section into three flat planes, that in the centre being horizontal, and the others slightly inclined from it. Very narrow roads are often sloped in one direction only, like one half of a convex road; and roads on the face of a steep hill are occasionally treated in this manner, the surface water being conducted towards the hill, and carried off by drains under the road. This plan has the advantage of checking any tendency in carriages to roll or turn over towards the least protected side of the road.

Wherever the substratum of a road is wet and soft, great care is necessary to make the bed solid. If the ground be boggy or marshy, it is desirable to form an embankment of sufficient thickness to compress the elastic foundation; such embankment being sometimes supported by faggots. Telford and most engineers recommend that ramming with stone-chips should be resorted to where the bed is wet and spongy; and that where soft clay occurs, a stratum of earth or of sand should be laid between it and the road materials, a precaution which tends to diminish the injurious effect of frost on a road with a clay bottom. Though great care is usually considered necessary in order to obtain a firm foundation, McAdam and some others have not only contended against its importance, but actually preferred, in certain cases, a yielding substratum to one of rock, on the supposition that the wear of the road is diminished by elasticity. Careful observations on the repairs of a road in Somersetshire, of which about seven miles are supported by a morass, and five or six by limestone rock, indicated a difference of expense in repair of about five to seven in favour of the morass, though it was so soft that the vibration caused by a carriage passing was sufficient to break the young ice in the side ditches; but extended experience seems to confirm the more general opinion in favour of a hard unyielding foundation.

Deep ditches should be cut for the efficient drainage of the road, which is of paramount importance; and these should be on the field side of the fences. They should extend to a depth of from 2 feet 6 inches to 4 feet below the bed of the road, according to the nature of the ground. The earth thrown out from them is commonly used in forming banks for the hedges; but in wet soils, where the ditches are made larger and deeper than usual, the additional earth excavated is applied to raising the bed of the road. Where brick or stone-covered drains are substituted for open channels, it is usual to build them with open joints, to allow the passage of water through the sides. Cross-drains of masonry are introduced at intervals to connect the side channels, and numerous minor drains filled with rubble stones or clean gravel are formed in the bed of the road. The latter are frequently of the kind called mitre-drains, which are made V shaped in plan, diverging from the centre of the bed, and extending diagonally to the sides, their angle being regulated by the longitudinal slope of the road, so that their inclination may not exceed 1 in 100. These may be placed about sixty yards apart, or closer in wet soils, and they receive the water that filters through the surface materials. In cuttings or excavations it is advisable to make drains to catch the water descending from the sides, and prevent its reaching the surface of the road.

In treating of the choice and application of the hard materials which compose the surface of the road, the formation of *metalled* roads, or those made of broken stone and similar materials, will be first considered; and afterwards that of the principal varieties of pavement.

Metalled or Broken-Stone Roads.—In the formation of metalled roads the system adopted in the great works of Telford and his followers, is the one most generally adopted by English engineers. The distinguishing characteristic of this system is the use of a rough pavement of hand-laid stones on the bed of the road, to support the small broken stone of which the surface is composed. In the very imperfect mode of road-making formerly practised (which scarcely deserves the name of a system), it was very common to cover a bad road with a large quantity of stones, often unbroken, and generally of very irregular dimensions. These stones, owing to their rounded form and the softness of the substratum, never consolidated into a hard surface, and in course of time sunk into the soft earth beneath, which worked up among the stones in the form of mud. Thus enormous quantities of stone were used without producing a good road, the stone sinking into the earth to a surprising extent. This evil is greatly diminished by good drainage, and by the use of stones of uniform size broken into angular pieces, which have a tendency to lock together into a hard and compact mass,—a fact of the highest importance in the science of road-making, and which appears to have been first prominently brought forward by the late Mr. McAdam. A great extent of excellent road has been made on the plan advocated by McAdam, who considered paving unnecessary, and laid the broken stone immediately on the surface of the earth, depending on its forming a hard crust impervious to water, so that the earth, being always kept dry, may have no tendency to work up among the metal or broken stone. McAdam used no stones exceeding six ounces in weight, and gave the preference to those of about one ounce, or an inch diameter, which he spread over the road in thin layers, each being worked over by carriages till in some degree consolidated; and he objected to the use of chalk or earth mixed with the stone for the purpose of binding it together. He considered a thickness of ten inches of broken stone, well consolidated, to be sufficient for bearing any load, even where the foundation is a morass, in which case he considered no intermediate substance necessary. Near Bristol, a road in which the metalling had worn down to a thickness of only four inches, was found to have kept the substratum of earth perfectly dry. But, satisfactory as this plan of road-making has proved in some cases, there are others in which it has failed, and some in which a very large quantity of stone has been applied before a firm road could be obtained. A road from Lewes to Eastbourne, made on Mr. McAdam's principle, is said to have required three feet of materials in many parts before it was consolidated, though it was ultimately brought into a good state.

The system of pitching or paving the bottom of a road has the advantage of preventing the subsoil from working up among the road materials, and, when well executed, of distributing the pressure of carriages over a larger base; while the size of the paving-stones themselves prevents their sinking into the earth, as small stones are liable to do. The pavement also acts as a drain to the surface materials. In addition to these, the plan has, in many situations, the advantage of economy, as the cost of a pavement is considerably less than that of an equal depth of well-broken stone. In most, if not all, of the cases in which the paving system has failed, the want of success may be attributed to very imperfect execution; as, if the stones are very irregular in size or badly set, or the thickness of metal is insufficient to protect the pavement from the shake of passing carriages, the stones become deranged, and the subsoil, working up among them, quickly spoils the road.

The case of the Highgate Archway road, which has been before alluded to, is a remarkable illustration of the absolute necessity of a firm bottoming under some circumstances. This road is over a subsoil of sand, clay, and gravel, and, being partly in a deep cutting (originally intended for a tunnel), is much exposed to the influx of water. The road, which is rather more than a mile and a half long, was originally made of a quantity of gravel and sand laid on the natural soil, and covered with broken flints and gravel; but this plan not succeeding, the road was taken up, and pieces of waste tin were laid on the subsoil, over which were spread gravel, flints, and broken stone. This expedient did not produce the desired effect, and at length, in 1829, the road was placed under the management of the Holyhead-road Commissioners, its proprietors having failed, notwithstanding an enormous outlay, and the application of 1200 cubic yards of gravel annually, to bring it into a satisfactory state. A thick coat of broken granite was spread on a portion of the road; but, owing to the unsoundness of the foundation, it never consolidated, the stones wearing into smooth pebbles by their attrition against one another, even down to the bottom of the mass. The commissioners therefore determined, as paving stones could not be procured without great expense, to lay a coating of Roman cement and gravel as a bed for the road-metal, an experiment which was attended with complete success. The work was executed by Macneill, and consists of a composition of Roman cement with eight times its quantity of washed gravel and sand, which, after being mixed in a box, was laid on the bed of the road to a thickness of six inches and a width of about eighteen feet. A few minutes after being laid, the upper surface was indented, by means of a triangular piece of wood sheeted with iron, with numerous channels or grooves, sloping about three inches from the centre to the sides, these channels serving for the stones to lie and fasten in, and for conducting any water that might percolate through them into the side drains. This measure, combined with an extraordinary extent of drainage, amounting in the whole to a length of 12,803 yards, proved so complete a remedy that, in the first winter after the cement was laid, coaches were able to go up with four horses at a trot with the heaviest loads, though before the improvement six horses had mounted with difficulty at a walking pace. The effect of the alteration on the wear of the road was equally satisfactory, four inches of quartz being worn away on the old bottom while only half an inch of the same stone was worn where laid on the cement foundation. The expenses of laying the cement composition, including the formation of the bed of the road, was about ten shillings per lineal yard, part of the gravel used being old. Macneill estimated the cost at from twelve to fifteen shillings per yard if new gravel were purchased.

The effect of a paved or concrete foundation in diminishing the draught appears, from the subjoined statement, founded on experiments with Mr. Macneill's road indicator, to be very great; but a more extensive series of trials is desirable for a comparison of different systems under various circumstances. The draught of a waggon weighing 21 cwt. was found to be as follows:—

On a well-made pavement	33 lbs.
On a road with six inches of hard broken stone on a rough pavement	46 „
On a similar road, with a foundation of Roman cement and gravel in lieu of pavement	46 „
On a road with a thick coating of broken stone on earth . .	65 „
On a road with a thick coating of gravel on earth . . .	147 „

For the formation of the pavement of a metalled road, almost any hard stone that may be easily dressed with the hammer may be used. The stones should be tolerably regular in size, and laid in rows with their broadest face downwards, the interstices being carefully filled up with stone-chippings, so as to pin the whole pavement together, and effectually prevent the earth from working up through the joints. In one of Telford's specifications for the Holyhead road, the dimensions of the stones for a pavement 30 feet wide are given as 7 inches deep in the middle of the road, 5 inches at 9 feet from the centre, 4 inches at 12 feet, and 3 inches at 15 fifteen feet, the stones to be laid lengthwise across the road, and the upper edge in no case to exceed 4 inches wide. All irregularities are to be broken off by the hammer, and the stone-chips used in packing the joints are directed to be wedged in by hand or with light hammers. No ramming is necessary, and it is desirable to prevent carts which are used in the conveyance of the road materials from being drawn upon the pavement before it is covered with broken stone.

Some road-makers use a pavement even on a substratum of rock, where it is uneven, but in many cases it is unnecessary; although, if the surface be smooth, it should be picked to a degree of roughness similar to that of a pavement, in order that the road materials may not slide upon it. Where paving the whole width of a road might be too expensive, the pavement is sometimes limited to a width of 16 or 18 feet in the centre. In situations where coarse stone of suitable quality can be easily procured, it is found to be cheaper to make a road with 6 inches of broken stone and a pavement, than with 10 inches depth of broken stone without paving. Mr. Wingrove, surveyor of the Bath roads, mentions the use of freestone brash, chalk, &c., for forming the foundation pavement of metalled roads. Of late years burnt clay ballast has been substituted for rough stone pavements in the brick earth or blue clay districts around London, with considerable success.

The quality and right application of the road-metal, or broken stone, which forms the surface of the road, is of great importance. As a general rule, the hardest stone is to be preferred; but this rule admits of some qualification, some very hard stones being found to wear much more rapidly than others of a softer but tougher quality. According to Parnell, whose experience rendered him a good authority, the best descriptions of road materials "consist of basalt, granite, quartz, syenite, and porphyry rocks." The whinstones found in different parts of the United Kingdom, Guernsey granite, Mountsorrel and Hartshill stone of Leicestershire, and the pebbles of Shropshire, Staffordshire, and Warwickshire, are among the best of the stones now commonly in use. The schistus stones will make smooth roads, being of a slaty and argillaceous structure, but they are rapidly destroyed by wet, by the pressure of wheels, and they occasion great expense in scraping and constantly laying on new coatings. Limestone is defective in the same respect. It wears away rapidly when wet, and therefore, when the traffic is very great, it is an expensive material. Sandstone is much too weak for the surface of a road; it will never make a hard one, but it is very well adapted to the purpose of a foundation pavement. Flints vary very much in quality as a road material. The hardest of them are nearly as good as the best limestone, but the softer kinds are quickly crushed by the wheels of carriages, and make heavy and dirty roads. Gravel, when it consists of the pebbles of the hard sorts of stones, is a good material, particularly when the pebbles are so large as to admit of their being broken; but when it consists of limestone, or sandstone, it is often a very bad one; for it wears so rapidly that the crust of a road made with it always consists of a large portion of the earthy matter to which it is reduced. This prevents the gravel from becoming consolidated, and renders a road made with it extremely defective with respect to that perfect hardness which it ought to have." Mr. Stevenson, in the article 'Road,' in the 'Edinburgh Encyclopædia,' states the distribution of road materials in the British islands to be partial and irregular. "Throughout Scotland, and even as far south as the approaching sources of the rivers Tees and Ribble, good road-metal is generally to be met with, containing the numerous varieties of granite, greenstone, basalt, porphyry, and limestone. South of this boundary, as far as the Trent and the Dee in Cheshire, the formation is chiefly carboniferous sandstone, and the softer varieties of limestone. In the southern counties chalk and gravel soils chiefly occur, affording flint and gravel, both of which, under proper management, make excellent roads. In North and South Wales we have all the varieties of road-metal which are common to Scotland. In Ireland they have excellent road materials, as granite and limestone are pretty generally distributed."

An interesting experiment has been tried on a part of the Holyhead road between London and Birmingham, as to the effect of iron amongst the road-metal in diminishing the wear of the road. The iron is cast in the form of cubes, about an inch square, and when the road was consolidated, holes large enough to receive them were picked in its surface. A single cube was then placed in each hole, so as to be level with the road, and the small stone-chips were beat down about the iron with a mallet. One of these iron cubes is placed in every four inches of surface. They very soon become firmly imbedded, so as not to be disturbed by the rolling of carriages or the feet of the horses; and to assist their consolidation, it is recommended to water the road freely, if the cubes should be inserted in dry weather. The iron was applied in March, 1835, since which time the portion of road in which they are used has continued in excellent repair, and the wear is materially diminished. Mr. Macneill, the patentee of this method of road-making, considered it particularly applicable to streets, on account of its durability, and believed that the expense would be trifling, as iron of the worst quality might be used. It may be observed that the draught on the piece of road on which the experiment is made is very easy, and that horses do not show any tendency to slip upon it.

In the choice of materials, the expense of conveying them to the road must be taken into consideration, but it is often better economy to fetch good stone from a great distance than to use that which is less durable, though readily procured; as, in addition to the expense of frequent repairs to a road formed with weak materials, great additional labour is imposed upon the horses, which have to wear down repeated coats of fresh stones. This is one of the points in which the inexperience and ignorance of road surveyors have often been displayed, cases having occurred in which an inferior material has been procured from a distance at great cost, while stone of excellent quality existed in abundance on the spot.

With regard to the best size of the broken stone for the surface of a road, both Telford and McAdam direct that no piece should exceed six or eight ounces in weight. In some districts the surveyors have been instructed to test the metal by a pair of scales and a six-ounce weight; but a more usual test is an iron ring 2½ inches in diameter, attached to a handle, through which every stone should be small enough to pass. Some writers have recommended that one inch should be the maximum diameter, but it is only the hardest and toughest materials that will bear breaking so small without much waste. The pieces should be as nearly cubical as may be, and should on no account be broken on the surface of the road; nor is it well to do it on the heap, the best method being to break one or two pieces at once on a large block of hard stone, the pieces being held steady by the iron ring that serves as a gauge. A sitting posture is considered best for those engaged in breaking road-metal, an operation which, under the modern system of road-making, gives employment to a great number of hands. Attempts have been made to perform this operation by machinery, but mechanical contrivances have not been found equal to manual labour. Pronged shovels are made use of in lifting the broken stone into barrows and carts, as they save labour by entering the heap with less resistance than ordinary shovels, and also prevent the admixture of earth with the metal.

The depth of metal on a paved foundation should be not less than 6 inches, and it should be laid on in two or three distinct layers, carefully spread with broad shovels, and carriages should work on each till it is in some degree consolidated before another is laid over it. While the metalling is fresh, men should attend to rake it in the ruts as fast as they are formed, and to pick off any large stones that may have previously escaped notice, as they are sure to work up to the surface. The sides of the road may be covered with the smaller portion of the metal, separated by a sieve with meshes of an inch square; and a layer of about an inch and a half of clean gravel is occasionally added over the whole surface in order to ease the draught while the road is new, though its effect on the road is rather injurious than otherwise, nothing being needed to bind the metal together. Rolling a road on which fresh materials have been laid is a measure of doubtful utility, the most effectual consolidation being produced by the working of carriages which are compelled to vary their tracks, and to run on the new metal, by placing wooden trestles across the road, and altering their position when necessary; the road is frequently raked as long as any loose stones remain.

Where the traffic is not sufficient to justify so expensive a mode of formation as that which has been described, good roads may be formed with broken stone only, increasing in thickness from 6 inches at the sides to 12 inches in the centre. If nothing better than gravel can be procured, Parnell recommends that a coat of 4 inches be laid on the prepared bed, and worked over till pretty firm; then a layer 3 inches thick, once screened, and finally three distinct layers of the gravel well riddled, and free from earth, clay, or stones exceeding an inch and a half in diameter; the road, when completed, to be 10 inches thick at the sides, and 16 in the centre, where the strongest and best part of the gravel should be laid. The drainage must be particularly attended to in a gravel road. Among the inferior materials occasionally used is limestone burnt to a vitreous state; but though formerly often used in districts where coal is abundant, it is not approved for carriage-ways by modern road-makers.

In completing a road it is necessary to form the side channels with care, and to provide against their being interfered with by branch or field roads. The footpath, which is usually about 5 feet wide, may be made of gravel or broken sandstone, and is required in the Holyhead road specifications to be level with the centre of the road, which is 6 inches above the sides. For fencing, walls are preferred where stone is plentiful, as they occupy less space than hedges, and have a neat appearance. If the stone should be of favourable shape, such walls may be built without mortar, except in the coping; but if on the side of an embankment, the walls should be always strongly built with mortar. A hedge-bank and ditch occupy a width of about 8 feet in ordinary cases, and the young quicks are protected by post and rail-fencing; but where timber is scarce, it is sometimes well to make the ditch and bank rather larger, so that the wooden railing may be dispensed with. In cuttings and some other situations a mound or bank without a hedge forms a convenient fence, and these, as well as hedge-banks, may be improved in appearance and durability by being swarded. All fences should be kept low, that they may not exclude sun and wind; and for the same reason trees or buildings that overshadow the road should be removed when practicable. The situation of toll-gates must be regulated by circumstances, but it is very desirable to avoid placing them either on, or at the bottom of, a hill, because such an arrangement is very liable to cause accidents. The gates, which, when single, may be 15 feet, or, when double, without a centre-post, 24 to 30 feet wide, are usually painted white, that they may be readily seen at night. They should be well lighted, and supplied with comfortable toll-houses, which, on some of the modern roads, are erected in an ornamental style. Parnell advises the use of milestones of light-coloured stone, and of larger dimensions than usual; but cast-iron posts have been extensively used, and on some roads cast-iron tablets mounted on stone. A convenient arrangement is a stone or post with two tablets inclined towards the road, so that persons travelling in either direction may see the distance of the town which they are approaching.

However well a metalled road may be made in the first instance, its preservation in a good state depends greatly on prompt and judicious repair. The mud that forms on the surface in wet weather should be scraped off and formed into heaps at the side (avoiding the side channels), until it is sufficiently dry for carting away: because, if left on the surface, it would, while moist, soften the road and cause it to break up, and after drying impede the running off of water from a subsequent shower. This operation has been usually performed by hand, but scraping-machines, patented by Messrs. Bourne and Harris, have been introduced with partial success, and have been said to diminish the labour fully one-half. The winter season, from October to April, is considered the best time for the addition of fresh materials, which are laid on in thin coats, and should always be applied as soon as any hollow capable of retaining water is observed. For the purpose of keeping a supply of broken stone always at hand, depôts for holding about twenty-four cubic yards of metal are formed by the road-side, at intervals of a quarter of a mile or less, from which the stone is taken to the required spot in barrows. When laid on the road, according to Parnell, it is not necessary to pick up the old surface, as the new metal keeps the part under it wet and soft, and soon works in. McAdam, however, recommended breaking up the surface of the road in every case where fresh stone is added.

Stone and Iron Tramways.—Though an improvement on ordinary pavement, this description of road may be considered as a link between metalled and paved roads, stone tracks having been occasionally applied to common roads, and with great benefit. Stone tramways consist of wheel-tracks formed of large blocks of stone, usually granite, the surface of which is made so smooth as to offer very little resistance to the rolling of the wheels, while the space between the tracks, being composed of broken stone, gravel, or rough pavement, affords secure footing for the horses. Iron tramways, in which cast or wrought iron plates are used instead of blocks of stone, have hitherto been very little used on ordinary roads, though their superior smoothness gives them a decided advantage, while their expense does not, as stated by Macneill, at all exceed that of granite. Iron tracks are sometimes made with a flat surface, but a slight concavity, as in Woodhouse's rail, which tends to keep the carriages more accurately in the right course, and is therefore an advantage when the vehicles used on the tramway are nearly uniform in width. The granite blocks used for stone tramways are generally from 3 to 6 feet long, 12 to 18 inches wide, and 8 to 12 inches deep. Great care is necessary in bedding such large blocks; and the joints require nice adjustment. They are frequently laid end to end without any fitting into each other, but it has been proposed to dovetail the ends together, to insert a small stone as a dowel between two blocks, to use iron clamps, or to join the stones with oak tree-nails. The granite tracks used on some steep ascents in the Holyhead road are bedded on a pavement 8 inches thick, packed and grouted, and a layer of 3 inches of broken stones not exceeding 1½ inch in diameter; a thin stratum of gravel, well rolled, being placed last of all to receive the blocks. When they are laid, the centre and side spaces are filled up with ordinary road material to the level of the tracks; a row of common granite paving-stones, about 6 inches deep, 5 wide, and 9 long, being laid along each side of the tracks to prevent loose materials working on to them. Mr. Stevenson, in the 'Edinburgh Encyclopædia,' recommends the use of smaller stones, as being cheaper and less liable to injury from vibration than those of the usual size. The dimensions recommended by him are 14 inches deep, 18 inches wide at the base, 12 inches wide at the top, and 6 to 9 inches long. The increased accuracy required in the numerous joints might probably counterbalance any advantage gained by the adoption of small stones.

The great saving of power effected by the use of tramways for ordinary carriages is shown by numerous experiments, some of which, tried on the granite tracks of the Commercial Road in London, proved that a well-made waggon will run with increasing velocity, by the force of gravity alone, down a mean slope of 1 in 155. On this road a loaded waggon weighing ten tons was drawn with apparent ease by a single horse, up an ascent of 1 in 274, for a distance of about two miles. On an iron tramway laid in 1816 by the Forth and Clyde canal company at Port Dundas, near Glasgow, a horse has taken a load of three tons on a cart weighing nine cwt., up an acclivity of 1 in 15, without difficulty, though he could not proceed with it on a common causeway with an easy line of draught; and the carters agree that the horses take up three tons upon the iron tracks as easily as they did twenty-four cwt. on the common causeway previously used.

In order to ascertain the comparative durability of different kinds of stone for tramways, and for paving generally, Mr. Walker tried some experiments on blocks laid in a toll gateway on the Commercial Road tramway, the results of which were as follows:—The blocks were 18 inches wide and 12 deep, and were laid down in March, 1830; and the loss given in the table was ascertained after they had been in use seventeen months, in August, 1831:—

Description of Stone.	Loss of Depth. Absolute.	Loss of Depth. Comparative.
Guernsey	·060 in.	1·000 in.
Herm[*]	·075	1·190
Budle[†]	·082	1·316
Blue Peterhead	·131	2·080
Heyton	·141	2·238
Red Aberdeen	·159	2·524
Dartmoor	·207	3·285
Blue Aberdeen	·225	3·571

Stone tramways have been adopted in many street pavements where a great traffic is carried on, particularly in some of the narrow streets in the city of London, with much advantage; but their application to acclivities on ordinary roads has hitherto been more limited than their merits deserve. By their judicious introduction on a few steep inclinations, many hilly roads might, at a small expense, be made nearly equal to level lines; and it is probable that such a measure would tend, in an important degree, to enable turnpike-roads to meet the formidable rivalry of railways. In his report to the Holyhead-road Commissioners in 1830, Mr. Macneill strongly recommends the application of stone or iron tracks to several hills, and states that an iron tramway laid down along the whole length of the road would reduce the expense of horse labour fully one half. "If," he writes, "a tramway were constructed of iron plates, the whole way from London to Birmingham, a coach carrying sixteen passengers might be drawn at the rate of ten miles an hour with only two horses, and one horse would be able to draw a post-chaise more easily than two now can, so that the expense of travelling might be reduced one half, and a similar reduction might be made in the charges for carrying goods. The expense of forming such a railway would be about 2500*l.* a mile, making the whole expense from London to Birmingham 271,000*l.*" In addition to the immediate advantages of such an improvement, it would remove one of the greatest obstacles to the successful use of steam locomotives on common roads.

Pavements.—The formation of paved roads on correct principles appears to have been well understood by the Romans, whose pavements show great care in their essential features,—a good foundation and accurate fitting of the stones. Some of the modern imitations of the Roman system in the street-pavements of Italy show the like attention to these important points, the paving-stones being set in mortar on a concrete foundation with a degree of accuracy that has led some writers to designate these roads *horizontal walls.* In some instances the blocks of stone used are of considerable depth; but they are often thin, and, being of large dimensions, have more the character of flag-stones than of ordinary paving blocks. At Naples and Florence, stones 2 feet square and 6 inches thick, laid diagonally across the road, and neatly set in Pozzuolano mortar, are used; the surfaces being chipped where declivities or turnings occur, to prevent the slipping of horses, which become very sure-footed from habit. Occasionally, as at Milan, different kinds of paving are laid for the wheel tracks and horse-path, so as to produce the effect of a stone tramway. These pavements have been recommended as models for imitation in paving the streets of London; but the durability with which they are constructed would form a disadvantage in a place where the pavement has to be frequently disturbed for the purpose of laying down or repairing water and gas-pipes, or cleansing the sewers; and it is probable that pavements which answer well for the light vehicles and limited traffic of many of the continental cities, would be found quite inadequate to bear the number of heavy carriages traversing the principal thoroughfares of the metropolis; of which some idea may be formed from the fact that from six o'clock, A.M., of March 16, to six o'clock, A.M., March 17, 1850, there were observed to pass over London Bridge, 4483 cabs, 4286 omnibuses, 9245 waggons and carts, and 2430 other vehicles, or 20,444 in all.

Another description of paved road, the origin of which is commonly referred to the Romans, is the *chaussée*, or roughly-paved causeway used in the principal highways of France and some other parts of the Continent. This kind of road has been much recommended for its durability when well made, but, unless laid with a degree of care that would render it too expensive for general adoption, it causes a very unpleasant and fatiguing jolting. In such roads the pavement usually covers only a part of the breadth of the road, leaving the sides available for the use of the light carriages in dry weather; and it has been suggested, that where the width of the roadway would allow, it might prove advantageous to form, in all great roads, a track of pavement or hard broken stone for winter use, and another of inferior materials for summer, both to save the wear of the hard road and increase the comfort of passengers. Such an arrangement is convenient in the principal approaches to great towns, where it is considered best to have the pavement at the sides, that carters may walk either on or near the footpaths, and that foot-passengers may not be incommoded by the dirt of the metalled road.

In Holland, pavements of brick, which are also probably derived from the practice of Roman engineers, are extensively used, not only for footpaths, but also for the passage of heavy carriages, which run on them with great facility. The bricks used for this purpose are thin, and well bedded in lime.

Common stone pavements are, by most writers, divided into two classes: *rubble* causeway, in which the stones are of irregular shape, and very imperfectly dressed with the hammer; and *dressed* causeway, which is formed of stones of larger size accurately squared and dressed. In both kinds the excellence of the pavement depends greatly on the firmness and evenness of the bed, and the careful fitting of the stones to each other, which may be accomplished with very irregular stones by judicious selection. If one stone be left a little higher or lower than those adjoining it, or if it become so in consequence of defective bedding, the jolting of carriages in passing over the defective place will quickly damage the pavement; the wheels acting like a rammer in driving the depressed stones deeper into the earth, while the derangement of the lateral support that each stone should receive from those adjoining it, occasions the dislocation of the pavement to a considerable distance, and the consequent working up of the earth through the disturbed joints. Defective joints form another fruitful source of injury and inconvenience both to the pavement itself and to the vehicles jolted over it. If, as is often the case in inferior pavements, the edges of two adjoining stones do not meet with accuracy, narrow wheels will have a tendency to slip into the joint, and by doing so, to wear the edges of the stones, till, as may be frequently seen, the surface of each stone is worn into a convex form that renders the footing of horses insecure, and causes the motion of vehicles drawn rapidly over them to consist of a series of bounds or leaps from one stone to another, accompanied by a degree of lateral slipping highly injurious to the carriage, while the irregular percussion produced tends greatly to the destruction of the pavement.

In order to procure a firm foundation, and to prevent earth from working up between the stones, it is advisable in the first instance to form a good carriage-way of gravel or broken stone, and to allow it to be used by carriages till consolidated, before laying the pavement. This plan is stated by Edgeworth, in his 'Essay on the Construction of Roads and Carriages,' 1817, to have been practised successfully by Major Taylor, of the Paving Board, in some pavements in Dublin, and it is strongly advocated by more recent road-makers. Where broken stone is laid to a considerable depth, it should, as in the case of metalled roads, be applied in thin layers, each being separately worked into a compact state. In streets of very great traffic, it is a good plan to lay a sub-pavement of old or inferior stones, bedded on broken stone, as a foundation for the surface pavement, a measure which has been practised with advantage in Paris; but of late years it has been the custom in London to form the bed of paved roads by means of a layer of gravel, perfectly clean, which is rudely converted into a species of concrete by floating the surface with lime-water. The bed of the pavement should be formed into a slight convexity, the slopes being about 2 inches in 10 feet. A thin coat of gravel or sand laid immediately under the paving blocks is of use in filling up slight irregularities in their shape, and enabling them to form a compact bed.

For the paving stones hard rectangular blocks of granite are preferred, though whinstone, limestone, and even freestone, may be used. Guernsey granite, as shown by the table in a previous column, appears to be the most durable, but it is more liable to become inconveniently smooth than some stones of inferior hardness, such as the Mount Sorrel or Aberdeen granite. The stones may vary, according to the traffic, from 6 to 10 inches deep, 6 to 18 inches long, and 4 to 18 inches wide; but it is very essential that the depth of all the blocks in one piece of pavement should be alike, and that where the width is unequal, the stones be so sorted that all used in one course should be uniform in this particular. The accurate dressing of the stones is a point often too little attended to; and an injudicious mode of forming contracts for paving, in which the payment has been by the square yard of paving laid, has, in connection with the effect of competition in bringing prices below the remunerating point, led to the use of stones in which the base is smaller than the upper surface, and which, when laid, scarcely come in contact with each other except at their upper edges. In some pavements the stones are made smaller at the top than the bottom, the joints being filled up with stone-chips, concrete, or an asphaltic composition; and in those of the more common construction the sides of the stones are occasionally hollowed, so as to receive a small quantity of gravel or mortar, which serves as a kind of dowelling. Ramming the stones with a heavy wooden hammer is a practice that has been much recommended, and it is considered that a more efficient application of the process, by means of a ramming-machine, or *portable monkey*, would remove some of the defects arising from imperfect bedding; but when the stones are well laid, and bedded in strong mortar, as the best recent pavements are, a few blows with a wooden maul of about 14 pounds weight are sufficient to fix them firmly in their place. Grouting with lime-water poured all over the pavement facilitates the binding of the whole together, and fills up the joints, so as to effectually prevent the working up of the substratum. The blocks are commonly laid in rows across the road, the joints in each row being different from those of the adjoining ones; but pavements of superior smoothness have been laid in courses stretching diagonally across the street, by which means all the joints are passed over by carriages with greater ease. This arrangement is particularly desirable at the intersection of streets, as it diminishes the risk of horses slipping. Longitudinal courses are objectionable on account of the tendency of narrow wheels to enter the joints. In paving steep inclinations, it is well to use narrow stones, on account of the number of cross-joints; or, if large stones be used, to cut deep furrows across their surface, to afford secure footing. A plan of paving for such situations, which has been found very effectual, is represented in the annexed diagram, in which the stones are so inclined as to present a series of steps. The chief objection to this plan seems to be the jolting caused to carriages, which produces so deafening a noise that, in one instance, such a pavement was taken up at the request of the inhabitants of the street. Many patents have been procured for plans of forming stone pavements in which the pressure of carriages might be simultaneously distributed over several stones, by various contrivances for dovetailing and otherwise fitting the stones together; but such plans are generally too complicated, requiring an accuracy of formation that would be very expensive, owing to the hardness of the stone. Thin blocks of stone, bedded in asphalte, have been tried, and appear to make a good pavement.

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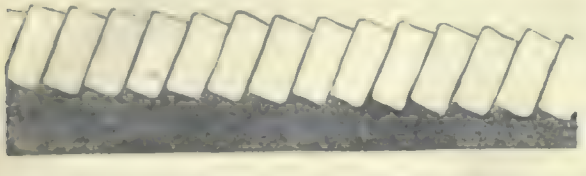
[*] Herm is an island adjoining Guernsey.

[†] A whinstone from Northumberland. All the rest are granites.



When completed, a thin coat of gravel spread over the surface is useful in diminishing the effect of the jolting of carriages on the new pavement. In case of taking up any part of a pavement to attend to water-pipes, &c., great care is necessary in relaying the part, in doing which it is well to apply some fresh broken stone to the bed, and to lay the paving stones without mortar, until the foundation is settled.

The serious defects of the common stone pavements have led to a variety of experiments on other methods of forming carriage-ways suitable for streets, of which the adoption of broken stone, or macadamised roads, has been the most general. Opinions differ widely as to the propriety of this measure, but an idea seems to be gaining ground that the comparative quietness of such a road, and its superior ease to passengers, are insufficient to counterbalance the increased draught of carriages, the dust of summer, the mud rapidly formed in wet weather, and the great expense of keeping in repair a metalled road when subjected to the constant wear of a busy town.

The enormous expense of maintaining some of the metalled roads in London has led to attention being given to various plans of paving with wood. A very coarse kind of wooden road, consisting of rough logs laid close together across the track, is much used in North America, under the name of *corduroy roads*, but the wooden pavement, properly so called, seems to have been first used in Russia, and tried on a limited scale at Vienna, New York, and some other places, within a few years. One of the earliest kinds used consists of blocks of fir or other wood cut into hexagonal cylinders, of 6 or 8 inches diameter, and from 8 to 12 or 15 inches deep, and placed close together, with the grain vertically. The blocks are sometimes tarred, or may be kyanised; but even where no such precaution is used, the wear is very trifling, as the swelling of the wood from moisture makes the joints very tight and impervious to water. Such a pavement is very smooth when first laid, but unless the foundation be very carefully prepared, it is liable to sink into hollows like the common stone pavement, owing to the want of cohesion between the individual blocks, a deficiency which it has been proposed to remedy by pegging or dowelling the pieces together, though their form is not very suitable for the purpose. Some specimens have been laid on a flooring of planks, to avoid this inconvenience. Numerous other systems of wood pavements have been adopted, but in spite of the incidental advantages (as in the case of the suppression of noise, &c.) they have been found to be so dangerous to horses as to render it necessary to abandon the use of that material.

Another description of road that has lately attracted much attention is that consisting of an asphaltic composition. Many attempts have been made to form roads of gravel and other materials united by natural oleaginous or gelatinous substances, or coal-tar, into a kind of concrete; but such attempts have seldom proved successful on a large scale. Mineral substances of similar character have proved more advantageous, and the native asphalte procured near Seyssel, in the department of l'Ain, and some other places, has been found to produce, when mixed with a small portion of native bitumen, a substance admirably adapted for the formation of smooth roads, and a variety of other important purposes. Its application to carriage-ways has been in this country chiefly confined to court-yards, for which, as well as for terraces and footpaths, it is very suitable. The asphaltic mastic of Seyssel, as prepared for use, consists of ninety-three parts of native asphalte reduced to powder, and seven parts of bitumen; the two being melted together, and a little fine gravel or sand stirred in with the mixture. The composition is ready for use when it simmers with a consistency similar to that of treacle, and it is spread while hot so as to form a coating about an inch thick upon a levelled foundation of concrete. The thickness of the asphalte is regulated by slips of wood or iron, which are often so disposed as to divide the pavement into ornamental compartments, the asphalte being made of various colours by the admixture of different kinds of sand or other substances. Where the ornamental character of the pavement forms a distinguishing feature, beautiful imitations of mosaic work may be executed with asphalte. The genuine natural asphalte possesses a degree of elasticity that renders it exceedingly durable; but artificial compounds in imitation of it generally require too much bitumen, and are injuriously affected by great changes of temperature. Some experiments have been made, but with very indifferent success, on the formation of carriage-ways with large blocks of asphaltic composition containing a considerable quantity of gravel or broken stone. [ASPHALTE.]

Foot-pavements of flag-stones require very little remark. The curbstones should be very hard, and firmly set in cement on a bed of gravel. They usually rise about 6 inches above the surface of the carriage-way, which may be made to abut immediately upon them, without the intervention of a gutter. Where gutters are introduced, those of cast-iron are to be preferred. The flagstones, which should never be less than 2½ or 3 inches thick, are commonly bedded in mortar on a layer of gravel; but sometimes, when there are no cellars underneath, are laid dry. The appearance of many of the new streets of London is greatly improved by the use of flagstones of extraordinary dimensions, extending the whole width of the pavement; and a similar appearance at much less cost may be obtained by the use of asphalte. A slight degree of slope should be given to the pavement, to conduct water to the gutters, for which purpose a fall of 1 inch in 10 feet is sufficient, while a steeper inclination is objectionable from its danger in slippery weather.

Among the substitutes for common Yorkshire flagstones that have been recommended, may be mentioned slate, which appears to be very durable. Some pavements or floors of this material have been laid at the London Docks, where, among other advantages, it is found preferable to wood in point of cleanliness. Trackways of slate 2 inches thick are found strong enough to bear waggons or carts with 4 or 5 tons of goods; and some are laid of only half that thickness on an old wooden floor.

A 'Treatise on Roads,' &c., by Sir Henry Parnell, of which a second edition was published in 1838, may be consulted with advantage by those desirous of obtaining further information on the theory and practice of road-making. The works of Bergeir, McAdam, Edgeworth, Sganzin, Schwilgué, Lehay, and several others; and the various Parliamentary Reports relating to roads from the commencement of the present century, as well as those of the Holyhead Road Commissioners, also contain much valuable matter on this subject. It may be interesting to add, as a means of forming an approximate idea of the importance of our ordinary roads, that the sum laid out in the repairs of the turnpike roads of England and Wales in 1857 was not less than 1,127,791*l.*, including the interest on the debt, or a sum of 182,034*l.*; and that the county roads cost 2,286,559*l.* There are no recent returns of the lengths of the different kinds of roadways, but the cost of maintaining a turnpike road may be taken at 50*l.* per mile, and that of county roads at 11*l.* per mile.

ROADSTEAD, a sheltered bay, or portion of a sea-coast, in which vessels may lie safely at anchor until the tide should allow of their entering the harbour or dock at the bottom of the bay, or to pass the bar of a river discharging into the same. There are other roadsteads upon open coasts, formed by reefs or sand-banks running parallel to, but at some distance from, the shore, which afford shelter from winds blowing in certain directions, and thus materially assist the coasting- trade. Portland Roads and Spithead are illustrations of the first class of roadsteads; Yarmouth and Deal Roads are of the latter class. Plymouth, Cherbourg, and Delaware Bay have been artificially converted into safe roadsteads, and the same result has been attained by the remarkable works executed at the Helder.

The essential conditions of a safe roadstead are, that it should present a large area of water-surface of great depth; that it should have good holding ground; and that it should be protected from all winds which are likely to create much agitation in the water. The entrance must be easy, and indeed it is preferable that there should be more than one entrance to a roadstead, so that a vessel driven by stress of weather may be able to make either the one or the other pass, or, if driven past one of them, may still have a chance of taking refuge in the other. It is precisely for this reason that the roadstead of the port of Vigo is one of the most admirable harbours of refuge in Europe; for the Islas da Bayona stretch across the mouth of the bay, leaving two channels near the shores of the main land, and an overlapped channel between the two islands. The artificial roadsteads at Plymouth and Cherbourg have two navigable passes, for the breakwaters are in both cases formed in deep water, and without connection with the shore; but neither of these marvellous triumphs of human ingenuity and perseverance are so efficient as is the natural screen at Vigo in checking the transmission of the external agitation. In the open roads, such as Deal and Yarmouth, when the wind blows parallel to the shores, or rather to the entrances, no protection whatever can be afforded; and indeed the vessels which may be engaged in such narrow passes, not having sea-room, are exposed to greater danger with such winds than if they were in open sea. To some extent, all roads must be exposed to inconvenience from the waves when the wind blows straight into their entrances; but if the shelter from the prevailing winds should be perfect, it would be found that the waves, driven through the narrow passes, would soon be lost in the large mass of still water behind the natural or artificial means of shelter.

A ship of the line requires a minimum depth of 30 feet, and an area of about 8½ to 10 acres to swing freely at its anchors; a 1000 ton commercial vessel would not require a greater depth than 21 or 22 feet, and the area it would occupy would be proportionally less. If there should be any probability of the transmission of the external agitation to the interior of the roads, the depth of water must be greater than either of those stated, so as to ensure a sufficient depth beneath the keels of the ships even when the waves are at their lowest points. In the best roads, there are usually harbours, docks, repairing slips, and other conveniences for the examination and repair of vessels, and at all times the value of a roadstead is materially increased if it should possess means for watering the ships which resort to it. Some of the best roads in the Mediterranean are of little practical value on account of the lack of fresh water in them; as, for instance, the roads of Cagliari, in the island of Sardinia, although there is a tolerably convenient little harbour at the head of the bay. The passes between the main land and the sheltering breakwater must be at least from 1200 to 2000 yards in width, to allow large vessels to enter easily when they have any heavy way on them.

ROASTING is that culinary process by which meat is brought from a raw to a cooked state more directly by the action of fire than by any other means except that of *broiling*. By the latter the heat is applied immediately and suddenly to the surface, by which it is hardened, so that the juices of the meat are greatly retained, evaporation being thereby prevented; while, by the former, the heat is applied gradually, the watery portion is evaporated, as well as the fat melted out to a considerable extent, till the progressive browning and hardening of the surface prevent the further escape of the juices. But the loss resulting from the evaporation of the watery portion, and to a certain degree, the melting of the fat, may be lessened by imitating in the first stages the process of broiling, namely, by applying the meat at the beginning quite close to the fire, so as to harden the outside, and then removing it to a great distance, and conducting the subsequent stages very slowly. About fifteen minutes is generally sufficient to effect this encrusting for a moderately sized joint, if the fire be brisk and clear, as it always ought to be for roasting, or if gas be used. "Every house should have a moveable piece of iron or steel, with a joint permitting it to be turned out of the way when not in use, screwed on the mantel-piece, with teeth fixed in it, so as to be able to hang the joint any distance from the fire." (Soyer's 'Shilling Cookery for the People.') The evaporation may be further restrained by beginning to dredge the meat with flour earlier than most cooks do. The above eminent authority recommends that "all dark meats, such as beef and mutton, should be put down to a sharp fire for at least fifteen minutes, then remove it back, and let it do gently. Lamb veal, and pork (if young and tender), should be done at a moderate fire. Veal even should be covered with paper. Fowls, &c., should be placed close to the fire, to set the skin." For young meats the process should be carried farther than for older meats. The loss of weight in roasting meat is much greater than by boiling: "By boiling, mutton loses one-fifth, and beef one-fourth; but by roasting, these meats lose about one-third of their weight. In roasting, the loss arises from the melting out of the fat and the evaporation of the water, but the nutritious matter remains condensed in the cooked solid; whereas, in boiling, the gelatine is partly abstracted. Roasted are therefore more nutritive than boiled meats." (Paris, 'On Diet.') The digestibility is also increased, especially in young meats, which are deficient in osmazome, to which the sapidity is mainly owing, and which during boiling passes into the water employed, while in roasting it is powerfully developed and almost entirely retained. "Young and viscid food, therefore, such as veal, chickens, &c., is more wholesome when roasted than when boiled, and are more easily digested." The best and most tender meat may, however, be rendered hard and indigestible by a careless or ignorant cook. Everybody knows the advantage of *slow boiling—slow roasting* is equally important. See Dr. Kitchener's 'Cook's Oracle,' in which the most sensible and racy instructions on this head are given; also in Miss Acton's 'Cookery,' as well as the different works of Alexis Soyer.

The digestibility is increased by the meat being well done, rather than under done; "for though in this latter state it may contain most nutriment, yet it will be less digestible on account of the density of its texture." This is of importance to remember when it is intended for the diet of convalescents, for whom broiled and roast meats are preferable to boiled.

ROBBERY is theft aggravated by the circumstance of the property stolen being taken from the person, or whilst it is under the protection of the person, of the owner or other lawful possessor, either by violence or putting in fear. This offence appears to have been formerly confined to cases of actual violence to the person, but in later times it has been extended to constructive violence by putting in fear, and not only to cases where property has been taken or delivered under a threat of bodily violence to the party robbed or to some other person, but also where the fear has resulted from apprehension of violence to his habitation or to his property, or where it has been occasioned by threats of accusing the party of the commission of an infamous crime.

Robbery was formerly regarded not as an aggravation of the crime of theft, but as a distinct and substantial crime. Latterly, however, robbery has been treated as an aggravation of theft, and it has been held that if, upon the trial of an indictment for larceny, it appear that the taking amounted to a robbery, the party may nevertheless be convicted of the larceny charged.

The stealing is said to be by violence when it is effected by doing any injury, however slight, to the person of the party robbed, or when the act of taking is accompanied by any degree of force for the purpose of overcoming resistance. A snatching or taking of property suddenly or unawares from the person, without some actual injury to the person, does not amount to robbery. If violence be used, it is sufficient to constitute robbery, although resorted to under the colour of executing legal process, or of the exercise of some other lawful authority. It is not essential to the offence of robbery that the violence should have been at first used for the purpose of obtaining the property, provided the violence be unlawful and the property is yielded up, or permitted to be taken, in order to prevent further violence.

Stealing is considered to be effected by threat of violence to the person, when possession of the thing stolen is obtained by any threat, menace, or other act calculated to excite fear or apprehension of violence, present or future, to the person of the party threatened or of any other party in whose welfare the party to whom the threat is addressed may feel interested. It is immaterial whether the threat, &c., be direct or indirect, or whether conveyed by words, gestures, or signs, or whether made under pretence of lawful claim or of acting under legal process or other lawful authority, or of asking charity, or of making a purchase, or under any other pretence. The existence of actual fear in the mind of the party robbed is not material, provided the act of stealing be accompanied by such threats or other acts as are calculated to create the expectation that force will be used in case of resistance. Where no actual violence is employed, and the threats, &c., used do not create any apprehension of violence or expectation that force will be resorted to in case of resistance, or if such apprehension or expectation has ceased to exist at the time when the property is taken, the offence of robbery is not committed. If property be taken by violence or by threats, &c., it is robbery, although the owner may have voluntarily exposed himself to the attack for the purpose of apprehending the offender.

At common law, robbery was a felony punishable by death, without regard to the quantity or value of the property stolen. The offender, however, was entitled to benefit of clergy [Benefit of Clergy], until this advantage was taken away in cases of robbery, under different circumstances of aggravation, by several statutes.

The offender was liable to be punished at the suit of the crown after a trial upon an indictment, and, in certain cases, when taken in the very act, upon a trial without indictment. The party robbed also was entitled to bring his criminal action or appeal [Appeal] against the robber, for the purpose as well of punishing the offender as of obtaining restitution of the property stolen.

The party robbed may without any formality retake his goods wherever he can find them, unless they have been waived or thrown away by the robber during his flight, or seized by the officer of the crown or of the lord of the franchise, or sold in open market. But after such waiver, seizure, or sale, the owner cannot retake them of his own authority. At common law a writ of restitution could be obtained only upon the successful prosecution of a writ of appeal. But the courts before which a party is convicted of robbery or of larceny are now authorised to award writs of, or make orders for, restitution of stolen goods (21 Hen. VIII. c. 11; 7 & 8 Geo. IV., c. 29, s. 57).

Robbery is punishable by penal servitude for life or for any term of years not less than three years, or by imprisonment for any term not exceeding three years, and for any period of solitary confinement during such imprisonment not exceeding one month at a time, or three months in the space of one year.

Upon an indictment for robbery, as well as for any other felony which includes an assault upon the person, the jury may acquit of the felony, and find a verdict of guilty of assault, against the party indicted, if the evidence will warrant such finding; for which assault the party may be sentenced to imprisonment for any term not exceeding three years.

Robbery, in the Roman law, was called Rapina, and the remedy of the injured person was the actio vi bonorum raptorum against the robber. Robbery was, in fact, a species of Furtum; for the definition of furtum was, "a fraudulent carrying off (contrectatio) of a moveable thing against the owner's consent." The word 'fraudulent" comprehended the notion of a person carrying off the thing for the purpose of making it his own. Rapina only differed from Furtum in being effected by force.

Furtum was committed in various ways, besides by taking another person's property. A debtor committed furtum, if he fraudulently carried off a thing which he had pledged to his creditor. It was furtum to use a thing that had been lent, for a different purpose from that for which it had been lent. Furtum was either manifestum or nec manifestum. It was furtum manifestum beyond all doubt when the thief was caught in the act; but there was a difference of opinion as to whether it was furtum manifestum or nec manifestum in a variety of cases. According to some writers, it was furtum manifestum if the thief was taken with the thing before he had reached the place to which he intended to carry it. Furtum which was not manifestum was nec manifestum. The Twelve Tables made the punishment of furtum manifestum a capital offence, that is, an offence the penalty for which affected a person's caput or status. The edict changed this into an actio quadrupli. The remedy in the case of furtum nec manifestum, which the Twelve Tables gave, was an actio dupli, which the edict retained. All persons could have the actio furti who had an interest in the preservation of the stolen thing; consequently others besides the owner might bring the action, a bailee for instance: and sometimes the owner could not bring it, as in the case of bailment, provided the bailee was a responsible person. If he was a responsible person, he was bound to make good the loss to the owner, and consequently could bring the action, and the owner could not. Condemnation in an actio furti was followed by infamia.

The owner of the thing might also bring his action for the recovery of the thing itself or its value.

The law of the Twelve Tables permitted a person to kill a thief who was detected in the act of theft in the night; and a thief might be killed in the day-time, if he defended himself with any weapon (telum). But the severity of the old civil law was gradually mitigated by the edict, and the offence of theft was, as already observed, only punishable by an action of furtum, and the consequent pecuniary penalties.

The Roman law of Furtum is stated in Gaius, iii. 183-209; *Dig.*, 47, tit. 2: *Inst.*, 4, tit. 1.

ROBES, MASTER OF THE, an officer of the household who has the ordering of the king's robes. By statute 51 Henry III., the "Gardein de la Garderobe de Roi," the warden of the king's wardrobe, was to make accompt yearly in the Exchequer, on the feast of St. Margaret. The office has always been one of great dignity. A female sovereign has a mistress of the robes. High privileges were conferred upon the office by King Henry VI., and others by King James I., who erected the office of master of the robes into a corporation.

ROBINIC ACID. An acid of doubtful composition, said to be contained in the root of the *Robinia pseudo-acacia*. It is crystalline and deliquesces in moist air.

ROCCELLIC ACID, ($C_{34}H_{32}O_8$?) obtained from the *Roccella tinctoria*. This acid crystallises in fine colourless needles of a silky lustre. It is insoluble in water, whether cold or hot; alcohol dissolves it readily, 100 parts of 0·819 density, at the boiling-point, taking up 55 parts. Ether also dissolves it easily: it melts at 266°, and solidifies at 251°.

The alkaline roccellates dissolve in water, and yield solutions which froth like soap; but when concentrated, the solutions cannot be drawn out in threads like those of other soaps. Roccellate of potash crystallises in small laminæ: the salt of lime is a white precipitate, insoluble in water, and contains 15·9 per cent. of base.

ROCELLININ. [LICHENS, COLOURING MATTERS OF.]

ROCHELLE SALT. [TARTARIC ACID.]

ROCK ALUM. [ALUM.]

ROCK CRYSTAL, [SILICON.]

ROCK SALT. [SODIUM.]

ROCK-WORK, in gardening, an elevation, composed of earth and other loose materials, and covered with stones and fragments of rock, &c., amongst which plants adapted for such a situation are grown. When the rock-work is managed skilfully, and in accordance with surrounding objects, it may be made to add much to the beauty and interest of the garden. In the first place a proper situation should be selected, and the character of the rocks should harmonise with the situation. Simple outlines and surfaces not broken into fantastic shapes, are best suited to show off the plants. The best stones for rock-work are those which resist the action of the air, and they may be selected according to convenience from the rocks of the neighbourhood in which they are used. The most irregular ought to be chosen, especially those with cavities in them, which may be filled with earth for the growth of mosses, ferns, and small plants. Frequently stones are met with covered with lichens, which, from their picturesque colours, have a pleasing effect. Of these, the *Lichen atroflavus*, *geographicus*, *ventosus*, *perellus*, and *stellaris*, are most common. Such stones are mostly large, and are best adapted for the base of the rock-work.

Although rock-work is intended to present a mountainous or rocky vegetation in a small space, yet there are many circumstances that prevent the growth of true mountain and rock plants in such a situation; but the dry ridges of earth and stones of which it is composed afford a favourable situation for the plants that chiefly occupy the dry soil of plains. On this account, small shrubs and creeping plants of any kind that will grow in a dry soil are selected for rock-work. Of these, the varieties are numerous, and the taste and care of the cultivator may be advantageously shown in the selection.

ROCKET is a cylindrical vessel or case, of pasteboard or metal, attached to one end of a light rod of wood, and containing a composition which, being fired, the vessel and rod are projected through the air by a force arising from the combustion.

Rockets have long been used as a means of making signals for the purpose of communication when the parties have been invisible from distance or darkness, or otherwise inaccessible to each other; and they have occasionally served the important purpose of determining the difference of longitude between two places. In the latter case the rocket is fired at some convenient spot between the stations, from both of which the explosion must be visible; and the latter being nearly instantaneous, the difference between the times at which it is observed, as indicated by chronometers regulated so as to show the mean times at the places, is the required difference of longitude. Rockets have also been constructed for the purpose of being used in warfare, and such missiles were so employed for the first time at the siege of Copenhagen in 1807.

In signal rockets the part of the case which contains the composition, by whose combustion the projectile force is produced, is joined, at the upper extremity, to a conical case containing the composition for producing the explosions or *stars* of light which constitute the signal, and the length of this part is always rather greater than the diameter of the cylindrical part of the case. Such rockets are made to weigh half a pound, one pound, or occasionally even two pounds. The exterior diameter of the one-pound rocket is 1¾ inch; the length of the cylindrical case is 12¾ inches, and the length of the conical head is 3⅓ inches. The rod is generally attached near the base and on one side of the rocket; its length is about 8 feet, or 60 diameters of the rocket, and its thickness is about half a diameter of the latter. The composition with which the cylinder is filled consists generally of saltpetre, sulphur, and charcoal or gunpowder; the whole is reduced to a mealed state, and well mixed together in the following proportions:—saltpetre, 4 lbs.; sulphur, 1 lb.; and charcoal, 1 lb. 8 oz. The composition which produces what are called the stars consists of saltpetre, 8 lbs.; sulphur, 2 lbs.; sulphide of antimony, 2 lbs.; mealed powder, 8 oz.; and isinglass, 3¾ oz. The latter is dissolved in one quart of vinegar, after which one pint of spirit of wine is added, and then the mealed composition is mixed with the liquid till the whole becomes of the same consistency as a stiff paste. It is then moulded into short cylinders, and when dry, these cylinders are packed into the head with a small bursting charge. When the composition of the rocket is burnt out, the burster blows open the head and frees the lighted stars.

The rocket case having been placed on a conical spindle, which passes a certain distance up the centre, the composition for burning is rammed or driven round it, so that in the interior about the axis a void space of a conical form is left in order that a considerable surface of the composition may be at once in a state of combustion. The neck of the rocket (the part to which the rod is attached), is then *choked*, or reduced in size, leaving a small hole or vent through which the fire is communicated to the composition. The combustion of the latter immediately takes place on all the concave conical surface about the void space just mentioned.

In order to understand the cause of the rocket's motion, let it be observed, that if the composition were to be fired within a vessel or case closed on all sides, the pressure of the gas generated would be equal in every direction, and the case would either burst in pieces, or, if sufficiently strong, would remain at rest while all the composition was being consumed. But, the case having an aperture or apertures at the choke or lower extremity of the cylinder, the pressure which would have taken place against that extremity is reduced by the escape of the gas into the atmosphere; and there is an excess of pressure on the head, which is not counteracted by a pressure on the other extremity, equal in amount to the pressure due to a surface of the size of the orifice, that is, disregarding the resistance of the atmosphere to the escape of gas; and this pressure impels the rocket forwards or upwards. This force acts in a manner similar to that by which a gun recoils when the charge is fired; but, in the latter case, the fluid escaping almost instantly from the bore, the force is one of impulse on the bottom of the chamber which ceases nearly as soon as it is generated; whereas, in a rocket, the composition continuing to burn during several seconds, the force of impulse becomes a force of pressure, which continues to act till the material is consumed. Hence it follows that a rocket ascends, or moves forward, with an accelerated motion till the resistance of the air becomes equal to the accelerative force: and when the composition is burnt out, the rocket falls to the ground. We see then that *cœteris paribus*, the larger the vent or aperture, the greater will be the pressure on the head, driving the rocket forward. But this is modified by the consideration that the smaller the aperture the greater will be the condensation, and, therefore, pressure of gas generated; or, in fact, that the gas should not be allowed to escape as fast as it is generated. Again, the more rapidly the gas is generated, or the stronger the composition is, the greater will be the pressure; but at the same time, the sooner will it be burnt out, and the stronger and heavier must be the case. These considerations are most important in the construction of the large military rocket, and will be found fully treated in Captain Boxer's 'Treatise on Gunnery,' p. 67, chapter on Rockets.

The rod serves to guide the rocket in its flight: for the common centre of gravity of the rocket and rod being a little below the top of the latter (in the one-pound rocket it is 2 feet from the upper extremity of the rocket, or 7 feet from the lower extremity of the rod); if we suppose the rocket to be fired vertically upwards, and a vibration should take place about the centre of gravity by any excess of pressure on one side arising from an irregularity in the burning of the composition, the resistance of the air against the long portion of the rod below that centre, like a force acting on the longer arm of a lever, will exceed the force by which the vibration is produced, since the latter force acts on the rocket and the upper part of the rod which constitutes the shorter arm of the lever; and thus the vibration is checked or prevented, and the rocket is enabled to ascend steadily. But, in proportion as the composition burns out, the common centre of gravity approaches nearer the middle of the whole length of the rocket and rod; and the resistance of the air acting at length nearly equally above and below that centre, it can no longer counteract any inequality in the burning of the composition. Thus, in falling, the top of the rocket, or the rocket end of the rod, is downwards.

The rod performs a similar service when the rocket is impelled horizontally or obliquely; for, while the force of projection is great enough to carry the rocket forward, and the centre of gravity of the whole is near the rocket end of the rod, the resistance of the air against the tail of the latter will nearly prevent any vibration; but, when the centre of gravity has got near the middle of the length, the head of the rocket begins to droop, and at length the whole comes obliquely to the ground. It has happened however, from the rod being too short or too light, that the weight of the rocket, when the latter had been projected with a small elevation, has so much incurvated the line of its path before the composition has burnt out, that the rod has turned over it, and the whole has been driven to the ground in a direction tending towards the place from whence it was projected. In signal rockets, the stick is fixed to the side of the cylinder, a very defective arrangement, as shown by Captain Boxer in his chapter on Rockets.

Rockets whose diameters vary from 1 to 2 inches have been found to ascend vertically to the height of about 500 yards; and those whose diameters vary from 2 to 3 inches, have ascended to the height of 1200 yards. The distances at which rockets can be seen vary from 35 to 40 miles; and the times of ascent from 7 to 10 seconds. (Robins's 'Tracts,' vol. ii.)

Rockets, to be employed as military projectiles, were invented by Sir William Congreve, and, in the British artillery service, a body of men, called the rocket troop, was organised expressly for their management. Sir William caused the rockets to be made with strong iron cases of cylindrical forms, and terminating at the head with a paraboloid or cone; and he attached the rod so that its axis should coincide in direction with that of the rocket. Five classes of rockets were first made, namely, 3, 6, 12, 24, and 32 pounders. The 32 pounders have now however been abolished.

The paraboloid head is hollow, and can be used as a shell by filling it with powder, or as a shot by leaving it empty. The 12 and 24 pounders can also be used as carcasses by substituting a conical carcass head with four vents for the paraboloid head. The shell is fitted with a fuze fixed in the base, that is, nearest the rocket composition. It also has a small hole at the apex, through which the bursting charge is introduced. Through this hole the boring bit is introduced when it is necessary to bore out any fuse composition for short ranges. When the ranges are very short, it is necessary to bore out some of the rocket composition also. But this is a dangerous operation and hardly repays the trouble. The stick is screwed into the bottom of the case, an iron disk, and round it are five vents for the escape of the gas. In order that the direction of their flight may be more certain, military rockets are, in general, fired from tubes fixed in stands in such a manner as to be adjustable to any elevation, and raised sufficiently above the ground to keep the stick off it; and the proper elevation, at least for the smaller rockets, is about one degree for each hundred yards in the required range. From their form they penetrate to a considerable depth when fired against timber or earth: 12 pounder rockets, after a range of 1200 yards, have been found to enter the ground obliquely as far as 22 feet. The principal inconvenience attending rocket practice is the powerful action of the wind when it blows in a direction perpendicular, and even oblique, to the intended line of flight. The effect is very peculiar, for the wind acting on the tail, a long lever, drives the head up into the wind. The rocket should therefore be laid to leeward.

Rockets, being much lighter than any other kind of ordnance, and capable of being used with or without carriages, are well adapted for conveyance in mountainous countries. When fired in volleys against troops, their effect is likely to create much disorder; and those which act as carcasses, when fired against buildings, will almost certainly cause their destruction. Besides being employed in the siege of Copenhagen, rockets were used at the bombardment of Flushing (1809); and in 1813 the British rocket-troop rendered considerable service at the battle of Leipzig. The advance of a French column against an inferior force of British troops was checked by a well directed fire of rockets at the passage of the Adour in the last-mentioned year; and it is said that the explosion of the powder-magazine which in 1840 produced such disastrous effects at Acre, was caused by the fall of a rocket on the building. Rockets were used both by the French and English before Sebastopool. A rocket was invented by Mr. Hale a few years ago to be used without a stick; the rocket was something similar to the Congreve rocket, but at the base, which is in form like the frustum of a cone, besides a large vent hole in the axis there were five smaller holes cut obliquely through the exterior surface of the conical part. These holes, termed "tangential holes," are made with the object of giving a rotatory movement to the rocket to keep it point foremost. [RIFLE.] The rocket was restrained by a spring in the tube till it had obtained sufficient initial velocity to prevent its drooping.

ROD. [PERCH.]

ROGATION DAYS. It was a general custom formerly, says Bourne, and it is still observed in many country parishes, to go round the bounds and limits of the parish on one of the three days preceding Holy Thursday; when the minister, accompanied by his churchwardens and parishioners, used to deprecate the vengeance of God, beg a blessing on the fruits of the earth, and preserve the rights and properties of the parish. The primitive custom used by Christians on this occasion was, for the people to accompany the bishop or some of the clergy into the fields, where Litanies where made, and the mercy of God implored, that he would avert the evils of plague and pestilence, that he would send them good and seasonable weather, and give them in due season the fruits of the earth. The Litanies or Rogations then used gave the name of Rogation Week to this time. They occur as early as A.D. 550, when they were first observed by Mamertius, bishop of Vienna, on account of the frequent earthquakes that happened, and the incursions of wild beasts, which laid in ruins and depopulated the city. (Walifred, Stral., c. 28, 'De Repub. Ecclesiast.') In the canons of Cuthbert, archbishop of Canterbury, made at Cloveshoo, in the year 747, it was ordered that Litanies, that is Rogations, should be observed by the clergy and people, with great reverence, on the seventh of the calends of May, according to the rites of the church of Rome, which terms this the Greater Litany, and also, according to the custom of our forefathers, on the three days before the Ascension of our Lord, with fastings, &c. (Wilkins, 'Concil. Brit.;' Spelm., *v.* 'Litania.') In the Book of Common Prayer they are still retained. The three Rogation Days are the Monday, Tuesday, and Wednesday before Holy Thursday, which are appointed fast days. The previous Sunday is Rogation Sunday.

Rogation Week, in the northern parts of England, is called Gang Week, from *to gang*, which in the north signifies to go. Gang-week, occurs in the rubric to John, c. 17, in the Saxon Gospels; and Gang-dagas are noticed in the laws both of Alfred and Athelstan.

(Brand's *Popular Antiq.*; Brady's *Clavis Calendaria.*)

ROGUE AND VAGABOND. [VAGRANT.]

ROLLING, ROLLERS. [IRON MANUFACTURE.]

ROLLING STOCK. [RAILWAY.]

ROLLS. [RECORDS.]

ROLLS-COURT, the Court of the Master of the Rolls, is usually held in the Rolls Buildings in Chancery Lane; which were originally a house or hospital for the reception of Jewish converts. When the Jews were banished from England by King Edward I., there was little use for an hospital of this kind; whereupon it was assigned to the Master of the Rolls, who had thenceforth the denomination of *Magister Rotulorum, Recordorum, &c., et Custos Domus Conversorum.* One or two converts were maintained on a poor pittance in this house in the 16th century.

ROLLS, MASTER OF THE, an officer of the Court of Chancery, second only to the chancellor himself. Originally he had, as the name implies, the custody of the rolls or recorded proceedings of that court, and, it seems also, of any other documentary matter belonging to that court. But the custody had long been merely nominal, and the actual care of them was vested in certain keepers, under the authority of an act of Parliament (1 & 2 Vict. c. 94), by which, however, very extensive powers are given to the Master of the Rolls with respect to the custody and use of them. This act further commits to him the records also of the Common-Law Courts and of the Court of Exchequer.

By what means the Master of the Rolls became divested of the peculiar duties indicated by the name, is a point of legal antiquarianism which has not been satisfactorily elucidated; nor is it quite clear when or how he came to sit to hear causes in equity. The chief duties of this officer now are judicial; but from his decrees there is an appeal to the chancellor, or lords justices.

ROMAN ALUM. [ALUM.]

ROMAN ARCHITECTURE. Although, as was said under ARCHITECTURE, the Romans derived their architecture, as they did most of their arts, immediately from the Greeks, yet they undoubtedly borrowed the circular arch, and the fondness for circularity in the plans of their buildings, from the Etruscans; and these features were what mainly brought about the modifications of style and ornamentation, the variety of form and the constructive peculiarities, which distinguish Roman architecture. We cannot here trace the progress of the various modifications: all we shall attempt is to show the leading characteristics of Roman architecture, especially marking its divergence from that of the Greeks, referring the reader to the article GRECIAN ARCHITECTURE for a general view of the parent style, and to COLUMN for a particular account of the Orders.

With regard merely to the orders, Roman architecture presents chiefly a corruption of the Doric and Ionic, for it may claim the Corinthian as almost entirely its own, the Roman examples of that order being not only numerous and varied, but at the same time exceedingly different in character from the almost solitary specimen of one with foliaged capitals which occurs in a Grecian building. [GRECIAN ARCHITECTURE.] But even as regards the application of the orders, there is a wide difference between the two styles; in the Roman they are frequently employed as mere decoration, the columns being *engaged* or attached to the walls, or in some cases (as that of triumphal arches) though the columns are insulated and advanced from the structure, they are in a manner detached from it, inasmuch as they do not support its general entablature, but merely projecting portions of it. Nor are these the only differences, for besides the frequent employment of pilasters as substitutes for columns—that is, as constituting the order without columns—the practice of *super-columniation*, or raising one order upon another, was by no means uncommon; a practice that was indeed a matter of necessity in such enormous edifices as the Colosseum, if columns were to be employed at all.

From all this it will be evident that, as regards the orders alone, there is a very marked difference between Roman and Grecian architecture; yet such difference is by no means the whole. If there were no other distinction between them, that arising from the arch, and diverse applications of its principles to vaults and domes, would be a very material one; but we also meet with a variety and complexity in Roman buildings of which there are no examples in those of Greece.

With the exception of the Erechtheium, or triple temple on the Acropolis of Athens, Greek temples were merely simple parallelograms, differing from each other as to plan only in the number and disposition of the columns around the cella [TEMPLE]; whereas by the adoption of the circular form in their plans, whether for the whole or parts of a building, the Romans introduced an important element of variety into architectural design. To this shape in the ground-plan is to be ascribed the origin of the *tholus*, or concave dome, which harmonizes so beautifully with all the rest, and renders the rotunda-shape at once the most picturesque and the most complete for internal effect,—that in which both unity and variety are thoroughly combined. [ROTUNDA.] The Pantheon alone would suffice to convince us that the Romans were not mere copyists, and that if the Greek orders deteriorated in their hands, they also added much to the art and greatly extended its powers by new appliances. As regards its exterior, the Pantheon presents what is certainly a strikingly picturesque (and what we consider to be also a consistent and appropriate, because a well-motived) combination, namely, that of a rectangular mass projecting from a larger circular one. In that example the body of the edifice, or rotunda itself, has no columns externally; but circular peristylar temples, or rotundas, whose cella was enclosed by an external colonnade, were not uncommon. Of this kind is the temple of the Sibyl, or, as it is otherwise called, that of Vesta, at Tivoli, an edifice of singular beauty, and highly interesting as a very peculiar and unique example of the Corinthian order. Edifices of this kind were covered with hemispherical domes, or with smaller sections of a sphere, which consequently did not show themselves much externally, as they were raised only over the *cella*, and therefore the lower part was concealed by the colonnade projecting around it. The dome of the Pantheon is hemispherical within, but is of very low proportions and flattened form without, for its spring commences at about the level of the first or lower cornice of the exterior cylinder, and is further reduced by the base of the outer portion of the dome being expanded and formed into separate cylindrical courses or gradini.

Polygonal forms of plan were sometimes employed, of which there is an instance in what is called the temple of Minerva Medica at Rome, which is circular on the exterior, but internally decagonal, with nine of its sides occupied by as many recesses, and the other by the doorway—a remarkable peculiarity, it being very unusual to enclose a polygon within a cylindrical structure, although not the contrary, nor to erect a cylinder upon a square or polygonal basement. Octagonal plans were by no means uncommon: such form was frequently made use of for the saloons of public baths; and there is an instance of an octagonal temple, supposed to have been dedicated to Jupiter, in one of the courts of Diocletian's palace at Spalatro. Of hexagonal structures we are acquainted with no example, but a court with six sides occurs in the remains of the temple of Baalbec, not however a regular hexagon, but of elongated figure, two of the sides being 110, and the remaining four 88 feet each. In the later periods of Roman architecture, circular and polygonal structures became more frequent, and those of the first-mentioned kind deviated considerably from the original simple rotundas and circular temples. An inner peristyle of columns was introduced so as to make a spacious circular or ring-shaped ambulatory around the centre, which was much loftier than the colonnade, being covered by a dome raised upon a cylindrical wall over the columns. What is now called San Stefano Rotunda, at Rome, supposed by some to have been originally a temple dedicated first to Faunus, and afterwards to the emperor Claudius, and by others to have been a public market, is a structure planned according to the arrangement just mentioned, with a circular Ionic colonnade of twenty columns and two piers. The church of Santa Costanza, supposed to have been erected by Constantine as a baptistery, and afterwards converted by him into a funeral chapel to his daughter Constantia, is a remarkable example, owing to the columns being not only coupled, but unusually disposed, and to there being arches springing from their entablature, that is, there are twenty-four columns (with composite capitals) placed in pairs, on the radii of the plan, or one behind the other, forming twelve inter-columns and as many arches; and as far as the mere arrangement goes, this interior is strikingly picturesque.

The circular form was a favourite one with the Romans for their sepulchral structures of a more pretending class than ordinary: following in this the example of the Etruscans. It will be sufficient here merely to mention those in honour of Augustus and Hadrian, an account of which has been given under MAUSOLEUM. The tomb of Cæcilia Metella is a low cylinder, the height being only 62 feet, while the diameter is 90; and it may be considered as nearly solid, the chamber or cella being no more than 19 feet in diameter. This cylindrical mass is raised upon a square substructure; which combination of the two forms is productive of agreeable contrast; and it was accordingly frequently resorted to. The tomb of Plautius Sylvanus near Tivoli consists also of a short cylindrical superstructure on a square basement, but is otherwise of peculiar design, one side of that stereobate being carried up so as to form a sort of low screen or frontispiece, decorated with six half-columns, and five upright tablets with inscriptions, between them. The tomb of Munatius Plancus, at Gaeta, is a simple circular structure, of low proportions, the height not exceeding the diameter, and therefore hardly to be called a tower, notwithstanding that it is now popularly called Roland's or Orlando's Tower. Of quite different character and design from any of the preceding, is the ancient Roman sepulchral monument at St. Remi, which consists of three stages; the first a square stereobate raised on gradini, and entirely covered on each side with sculptures in relief; the next is also square with an attached fluted Corinthian angle, and an open arch on each side; and the uppermost is a Corinthian rotunda, forming an open or monopteral temple (that is, without any cella), the centre of which is occupied by two statues.

As instances of other combinations, we may refer to what is called the Tomb of Virgil, near Naples, consisting of a square substructure surmounted by a conical one; to the Roman monument at Constantina, in Africa, conjectured to have been a cenotaph in honour of Constantine, the lower portion of which is a cylindrical structure surrounded by a peristyle of twenty-four Doric columns, and carried up as a lofty cone, in receding courses or gradini, leaving at its summit a platform for an equestrian statue.

These notices may serve to convey some idea of the variety aimed at by the Romans in the distribution of the plans and general masses of their edifices, independently of decoration. Their Thermæ, or public baths, a class of structures remarkable for their vast extent and magnificence, are most interesting studies of combinations of plan, as they were not merely baths, but places of public resort and amusement, and consisted of an assemblage of courts, porticos, libraries, and spacious saloons and galleries, most of which presented some peculiarity of form and distribution. [BATHS.] If therefore we estimate Roman architecture by the manifold resources which it opened to the art, rather than by its debasement of what it borrowed from that of Greece, we shall find much in it both to admire and to imitate, as well as to censure and to avoid. Its Greek rival has nothing that will bear a parallel with it in this respect. Judging from its remains, we can see little in it that answers to the title of interior architecture; whereas some of the Roman temples were striking on account both of the size and the magnificence of their interiors. That of the Pantheon has been already referred to; a very different example is the Temple of Peace, erected by Vespasian. What was its external design is now altogether doubtful, as only the ruins remain, but its interior is very remarkable, the plan being divided in its breadth into three nearly equal portions, the centre one of which formed a spacious nave, terminating in a large semicircular tribune, or apsis, covered by a semidome. This nave was disposed in three compartments, presenting as many arches of exceedingly wide proportions, opening into as many divisions of the lateral portions of the plan, which did not constitute continuous aisles along the nave, but small chapels or recesses. Of these the centre one on each side terminated, like the nave, in a semicircular tribune, of the same dimensions as that apsis, so as to form a transept, and give the whole a marked cruciform appearance. The side divisions were covered by semicircular vaults, concentric with the arches opening into the nave; and this latter had a vaulted roof, in three groins or compartments, the ribs of which sprung from eight Corinthian columns, placed against the piers of the arches. Besides other peculiarities, we have here an instance of the effect resulting from the application of the semicircular form to plans in interiors, and of further varieties of design arising out of it, for the semidomes of the tribunes exhibit a rich specimen of coffering, being composed of octagons and squares.

The temple of Venus and Roma, built by Hadrian in the Roman Forum, would seem from recent excavations to have been one of the most splendid edifices in the city. According to the plan of M. Caristie, the temple stood in the centre of a quadrilateral enclosure, or peribolus, measuring 525 by 318 feet, and was enclosed by double colonnades of the Corinthian order, consisting altogether of 264 columns. The temple itself was of the same order, upon a considerably larger scale, and its dimensions about 350 by 166 feet. It was consequently large in proportion to the area within which it stood; and when viewed in combination with the extended files of columns around it, must have produced a powerful effect,—one in which harmony and regularity were blended with contrast. The interior, judging from the indications afforded by the ruins, must have been equally splendid and picturesque in character.

The Romans seem to have affected the practice of grouping buildings together as features in one general symmetrical plan. Their temples and basilicas were frequently placed, as the principal architectural objects, at the extremity of a forum, or other regular area enclosed with colonnades. The temple of Nerva stood at one end of, and partly projected into an enclosure (measuring about 360 by 160 feet), the entrance end of which had five open arches, and the sides were formed by screen walls, decorated with Corinthian pilasters, and columns immediately before them, over which the entablature formed breaks. Of Trajan's forum, which was surrounded not only by colonnades, but various stately edifices, nothing now remains except the celebrated triumphal column that occupied its centre, and which, so placed as a principal object, must have heightened the splendour of the whole. Like that of Nerva, the temple of Antoninus and Faustina was placed at one end of a court of moderate dimensions, whose sides were adorned with coupled columns placed immediately against the walls; and only the portico part of the temple (a Corinthian hexastyle, triprostyle) [PORTICO] advanced into the enclosed area in front. The forum of Caracalla was nearly a square, entirely surrounded by arcades, presenting thirteen arches on each of the longer and eleven on each of the shorter sides. In the centre was a Corinthian temple very similar in plan to the Pantheon, with an hexastyle, triprostyle portico in front, and remarkable for having inner columns behind the second from each angle, so that there was a double range of them at each end, and the central space within the portico was a perfect square equal to three intercolumns.

The mention we have incidentally made in regard to these temples may not improperly be followed by some additional remarks upon Roman edifices of that class. Unlike those of Greece, peripteral temples were of comparatively rare occurrence among the Romans; they were mostly prostyle, the portico being attached only in continuation of the cella, whose walls formed the flanks of the building, though the order of the portico was frequently continued along them either in half-columns or pilasters. Such is the plan of that celebrated one at Nismes, known by the name of the Maison Quarrée, which is a Corinthian hexastyle, pseudo-peripteral, the cella being ornamented with attached columns, thereby making ten intercolumns on each flank, three of which are open, or belong to the portico, which latter is accordingly *triprostyle*. The Corinthian temple at Assisi was similar in plan, except that it was not pseudo-peripteral, the sides of the cella being plain. That of Fortuna Virilis at Rome was an Ionic tetrastyle, diprostyle, and pseudo-peripteral. Besides contributing to variety, temples of this kind possess a certain variety of effect in themselves, owing to the depth of the portico, and the contrast between that part and the cella. The portico announced itself more decidedly as the façade *par excellence;* particularly as such temples were generally raised upon a stereobate continued as pedestals to enclose the steps leading up to them in front, and which sometimes, as in the temple of Nerva, and that of Antoninus and Faustina, projected very considerably.

As our object is rather to direct attention to the modes of composition affected by the Romans and the elements of their style, than to describe their chief architectural monuments, either historically or according to their respective classes and destination, we proceed now to consider some of the individual peculiarities and features belonging to their buildings. In the application of sculpture, particularly of statues, they were prodigal; but they employed the latter chiefly as architectural accessories, frequently placing them over columns, or on the summits of their edifices as acroteria to pediments, by way of giving variety to the outline of their buildings, and also of indicating at first sight their particular appropriation—a practice almost unknown to the Greeks, there being only one instance of it. The abundant use of statues led to the adoption of the niche—a feature unknown in Greek architecture—as a convenient mode of inserting them within the surface of walls, and thereby decorating them; at the same time space was gained in interiors, where, if otherwise placed, they would have taken up room. Niches frequently occur in Roman temples and baths. [NICHE.]

These various applications of curvilinear forms, both in plan and elevation, undoubtedly furnished Roman architecture with resources unknown to that of Greece. Nor can it be denied that the arch itself is a very beautiful feature, although it was employed by the Romans to such excess as rather to occasion monotony than to contribute to variety of design; the amphitheatres and similar works of the Romans consisting only of continuous tiers of arches, which constituted their more strongly marked features, the columns placed against their tiers being merely ornamental accessories, and comparatively of little effect, and even that not of the very best kind. There was one class of structures however, which, though consisting uniformly of arches and piers alone, were eminently impressive and picturesque, namely, the Roman aqueducts, works of extraordinary grandeur, if estimated by their prodigious extent, and the colossal massiveness of their construction, but not otherwise entitled to be termed magnificent, their architecture being in the plainest and severest style. In these there were sometimes two or even more tiers of arches, at others only a single one, as in that at Metz on the Moselle, which has exceedingly lofty arches, or, to speak more correctly, arches on exceedingly lofty piers, divided by offsets into three stages, the effect of which is no less advantageous than it is uncommon.

Another practice was eventually adopted, by means of which the arch and column became amalgamated as integral parts of the same ordinance, namely, that of supporting arches upon columns, making them spring either directly from their capitals or from an entablature-shaped block over them. This practice is commonly condemned as barbarous, but in our opinion somewhat too hastily, and with more of prejudice than of fair examination. That it was introduced during the decline of the art, and that it was an innovation subversive of former principles, is not to be denied. Yet if it must be reprobated, it ought to be so for its own demerits, not as an innovation: for all invention is such. It appears a very poor argument against it, to say that columns were originally designed to support horizontal architraves: we do not see how that circumstance, of necessity, renders every other application inadmissible. Where columns are employed to support, it certainly cannot be alleged that they are idle unmeaning expletives; nor that they are mutilated by being apparently partly embedded in the wall behind them. One very great advantage attending the combination of the arch with the column as its support, is that it allows the openings to be considerably wider than they otherwise could be, because such intervals as would produce a poor and straggling effect in a colonnade, become well proportioned and agreeable when spanned by arches.

Of the two Grecian orders, the Roman specimens usually referred to, namely, the Doric of the theatre of Marcellus, and the Ionic of that building and the temple of Fortuna Virilis, are exceedingly poor and meagre, spiritless and tasteless; while the Ionic of the temple of Concord may be pronounced detestable. In this last example the volutes of the capitals are turned diagonally, a mode afterwards adopted by Scamozzi for that order, and also practised in what is called the Composite. Even when comparatively pleasing in its contours, the Roman Ionic capital is poor and devoid of expression, in consequence of the smallness of the volutes, which is such that they almost cease to be characteristic features of the order. To this defect may be added the meagreness arising from the few revolutions made by the spirals, and the omission of intermediate ones; and also the harshness occasioned by the great projection of the ovalo, the narrowness of the face of the capital above it, and by that part forming a straight line, instead of the gracefully-flowing festoon-hem which unites the volutes together in all the Athenian specimens of the order. Numerous studies of both voluted and foliaged capitals may be seen in Piranesi's 'Magnificenza de' Romani;' and the variety of composition displayed in the latter very greatly exceeds what would be imagined by those who are acquainted only with what are referred to as standard examples of that order. This last may in fact be emphatically denominated the Roman order, although such distinctive title is usually applied to what is otherwise called the Composite, but which is only a variety of the foliage-capitalled class, and by no means the most striking as such, there being instances of compound capitals, in which griffins, eagles, human figures, or masks, are introduced above the foliage; consequently, if the voluted variety is to be received as a separate order, each of the others is quite as much entitled to the same distinction. How far the ordinary Corinthian capital differs from that in which the small volutes, or caulicoli, at the angles of the abacus are developed, and enlarged to the size of those of the Roman Ionic capital, may at once be seen by referring to COLUMN, col. 33, where a half of each example is placed in juxtaposition; and at col. 45 will be found a similar comparison between the capitals of the Tivoli Corinthian and that of the monument of Lysicrates. The contrast presented by the two last is striking enough, there being no similarity of character, but merely such degree of resemblance as serves to make the differences the more obvious. And if that Tivoli example be compared with the one shown in the other cut, and which may be received as an average sample of the order, it will be tolerably evident, even from such comparison alone, that the foliaged capital was treated by the Romans in a variety of modes and in a free artistical spirit. Neither are such distinctions confined to the capitals alone, for different examples present equal diversity in their entablatures and cornices. That of the Tivoli temple is remarkable throughout; and has such a peculiar character stamped upon it, that it almost deserves to be considered a separate order—certainly much more so than the Composite. Among other examples, that of the three columns of the temple of Jupiter Stator is the richest and most elegant in its capital, and is beautifully composed throughout. The Romans in fact bestowed as great diversity of character and expression upon this order, as the Greeks had done upon their Doric and Ionic.

For information respecting Roman buildings adapted to particular purposes, the reader is referred to the articles ARCH, TRIUMPHAL; AMPHITHEATRE; AQUEDUCT; BASILICA; BATHS; FORUM; MAUSOLEUM; TEMPLE; THEATRE, &c.

ROMAN CATHOLICS. [CATHOLIC CHURCH; RECUSANTS.]

ROMAN CATHOLICS AND JEWS. By the act 9 & 10 Vict., cap. 59, passed August 18, 1846, intituled "An Act to relieve her Majesty's subjects from certain penalties and liabilities in regard to religious opinions;" all the previous Acts and parts of Acts imposing disabilities on the professors of the Roman Catholic or Jewish religions were repealed, of which a portion, as far as Roman Catholics were concerned, had been indirectly removed by the Roman Catholic Relief Act. On August 1, 1851, however, was passed an Act 14 & 15 Vict., cap. 60, "To prevent the assumption of certain Ecclesiastical Titles in respect of places in the United Kingdom," by which a penalty of 100*l.* was imposed on any one assuming the title of archbishop, bishop, or dean of any province, place, or district in the United Kingdom; and which declared any such creation by the see of Rome to be illegal and void. It also made illegal and void, punishable with the like pecuniary penalty, the publication of any bull, brief, rescript, letters apostolical, or any other instrument or writing constituting such province or district, whether such district be or be not the see or diocese, or deanery, of the established church. On July 23, 1858, likewise was passed the 21 & 22 Vict., cap. 19, intituled "An Act to provide for the relief of her Majesty's subjects professing the Jewish religion," by which Jews on taking the oath before sitting in parliament, may be relieved, by a resolution of the house, from making the declaration, "I make this declaration on the true faith of a Christian;" and these words are to be omitted in every other oath, except on making presentation to an ecclesiastical benefice. Jews are also declared incapable of holding the office of lord-lieutenant of Ireland, lord chancellor of Great Britain or Ireland, or high commissioner of the general assembly of the church of Scotland. The right of presentations to ecclesiastical benefices, vested in Jews, is devolved in the archbishop of Canterbury, nor are Jews to advise in the disposal of such matters; a contravention of these provisions to be deemed a misdemeanour, and a conviction entails a disability of serving the crown in any office, civil or military, whatever.

ROMAN LAW. The historical origin of the Roman law is unknown, and its fundamental principles, some of which even survived the legislation of Justinian, are older than the oldest records of Italian history. The foundation of the strict rules of the Roman law as to familia, agnatio, marriage, testaments, succession to intestates, and ownership, was no doubt custom, which, being recognised by the sovereign power, became law. As in many other states of antiquity, the connection of the civil with the ecclesiastical or sacred law was most intimate; or rather, we may consider the law of religion as originally comprehending all other law, and its interpretation as belonging to the priests and the king exclusively. There was, however, direct legislation even in the period of the kings. These laws, which are mentioned under the name of Leges Regiæ, were proposed by the king, with the approbation of the senate, and confirmed by the populus in the Comitia Curiata, and, after the constitution of Servius Tullius, in the Comitia Centuriata. That there were remains of this ancient legislation existing even in the Imperial period, is certain, as appears from the notice of the Jus Civile Papirianum or Papisianum, which the Pontifex Maximus Papirius is said to have compiled from these sources, about or immediately after the expulsion of Tarquinius Superbus ('Dig.,' i., tit. 2), and from the distinct references to these Leges made by late writers. Still there is great uncertainty as to the exact date of the compilation of Papirius, and its real character. Even his name is not quite certain, as he is variously called Caius, Sextus, and Publius. (Dion. Hal., iii. 36; 'Dig.,' i., tit. 2.)

But the earliest legislation of which we have any important remains is the compilation of the code called the Twelve Tables. The original bronze tables indeed are said to have perished in the conflagration of the city after its capture by the Gauls, but they were satisfactorily restored from copies and from memory, for no ancient writer who cites them ever expresses a doubt as to the genuineness of their contents. It is the tradition that a commission was sent to Athens and the Greek states of Italy, for the purpose of examining into and collecting what was most useful in their codes; and it is also said that Hermodorus of Ephesus, then an exile in Rome, gave his assistance in the compilation of the code. There is nothing improbable in this story, and yet it is undeniable that the laws of the Tables were based on Roman and not on Greek or Athenian law. Their object was to confirm and define perhaps rather than to enlarge or alter the Roman law; and it is probable that the laws of Solon and those of other Greek states, if they had any effect on the legislation of the Decemviri, served rather as models of form than as sources of positive rules.

Ten tables were completed and made public by the Decemviri, in B.C. 451, and in the following year two other tables were added. This compilation is quoted by the ancient writers by various titles: Lex XII. Tabularum, Leges XII., sometimes XII. simply (Cic., 'Legg.,' ii. 23), Lex Decemviralis, and others. The rules contained in these tables long continued to be the foundation of Roman law, and they were never formally repealed. The laws themselves were considered as a text book, and they were commented on by the jurists as late as the age of the Antonines, when Gaius wrote a commentary on them in six books ('Ad Legem XII. Tabularum'). The actions of the old Roman law, called Legitimæ, or Legis Actiones, were founded on the provisions of the Twelve Tables, and the demand of the complainant could only be made in the precise terms which were used in the Tables. (Gaius, iv. 11.) The rights of action were consequently very limited, and they were only subsequently extended by the edicts of the prætors. The brevity and obscurity of this ancient legislation rendered interpretation necessary in order to give the laws any application; and both the interpretation of the laws and the framing of the proper forms of action belonged to the College of Pontifices, who yearly appointed a member of their own body to decide in all doubtful cases. The civil law was thus still inseparably connected with that of religion (Jus Pontificium), and its interpretation and the knowledge of the forms of procedure were still the exclusive possession of the patricians.

The scanty fragments of the Twelve Tables hardly enable us to form a judgment of their character or a proper estimate of the commendation bestowed on them by Cicero ('De Or.,' i. 43). It seems to have been the object of the compilers to make a complete set of rules both as to religious and civil matters; and they did not confine themselves to what the Romans called private law, but they comprised also public law. ('Fons publici privatique juris,' Liv., iii. 34.) They contained provisions as to testaments, successions to intestates, the care of persons of unsound mind, theft, homicide, interments, &c.

They also comprised enactments which affected a man's status, as, for instance, the law contained in one of the two last Tables, which did not allow to a marriage contracted between a patrician and a plebeian the character of a legal Roman marriage, or, in other words, declared that between patricians and plebeians there could be no Connubium. Though great changes were made in the Jus Publicum by the various enactments which gave to the plebeians the same rights as the patricians, and by those which concerned public administration, the fundamental principles of the Jus Privatum, which were contained in the Tables, remained unchanged, and are referred to by jurists as late as the time of Ulpian.

The old Leges Regiæ, which were collected into one body by Papirius, were commented on by Granius Flaccus in the time of Julius Cæsar ('Dig.,' 50, tit. 16, s. 144), and thus they were probably preserved. The fragments of these laws have been often collected, but the best essay upon them is by Dirksen, 'Versuchen zur Kritik und Auslegung der Quellen des Römischen Rechts,' Leipzig, 1823. The fragments of the Twelve Tables also have been often collected. The best work on the subject is that by James Godefroy (Jac. Gothofredus), which, with the more recent work of Dirksen, 'Uebersicht der bisherigen Versuche zur Kritik und Herstellung des Textes der Zwölf-Tafel-Fragmente,' Leipzig, 1824, seems to have exhausted the subject.

For about one hundred years after the legislation of the Decemviri, the patricians retained their exclusive possession of the forms of procedure. Appius Claudius Cæcus drew up a book of the forms of actions, which it is said that his clerk, Cnæus Flavius, stole and published; the fact of the theft may be doubted, though that of the publication of the forms of procedure, and of a list of the Dies Fasti and Nefasti, rests on sufficient evidence. The book thus made public by Flavius was called Jus Civile Flavianum; but like that of Papirius it was only a compilation. The publication of these forms must have had a great effect on the practice of the law: it was in reality equivalent to an extension of the privileges of the plebeians. Subsequently Sextus Ælius published another work, called 'Jus Ælianum,' which was more complete than that of Flavius. This work, which was extant in the time of Pomponius ('Dig.,' i., tit. 2, s. 2, § 39), was also called 'Tripertita,' from the circumstance of its containing the laws of the Twelve Tables, a commentary upon them (interpretatio), and the Legis Actiones. This work of Ælius appears to have been considered in later times as one of the chief sources of the civil law (veluti cunabula juris); and he received from his contemporary Ennius the name of "wise":—

"Egregie Cordatus homo Caius Ælius Sextus."

Sextus Ælius was Curule Ædile, B.C. 200, and Consul, B.C. 198.

In the Republican period new laws (leges) were enacted both in the Comitia Centuriata and in the Comitia Tributa. The Leges Curiatæ, which were enacted by the curiæ, were limited to cases of adrogation and the conferring of the imperium. The Comitia Centuriata were made independent of the senate by the Lex Publilia (Liv., viii. 12), which declared that the leges passed in these Comitia should not require the confirmation of the senate. The leges passed in the Comitia Tributa were properly called Leges Tributæ or Plebiscita, and originally they were merely proposals for a law which were laid before the senate and confirmed by the curiæ. But the Lex Publilia (B.C. 336), and subsequently the Lex Hortensia (B.C. 286), gave to the Plebiscita the full force of leges without the consent of the senate (Liv., viii. 12; Gaius, i. 3; Gell., xv. 27); and a Plebiscitum was accordingly sometimes called a lex. The leges generally took their name from the gentile name of the magistrate who proposed them (rogavit), or, if he was a consul, from the name of both consuls, as Lex Ælia or Ælia Sentia, Papia or Papia Poppæa. If the proposer of the law was a dictator, prætor, or tribune, the Lex, or Plebiscitum, as the case might be, took its name from the proposer only, as Lex Hortensia. Sometimes the object of the lex was indicated by a descriptive term, as Lex Cincia de donis et muneribus.

The Senatus Consulta also formed a source of law under the Republic. That a senatus consultum in the time of Gaius (i. 4) should have the force of law (vicem legis optinet) may be easily admitted; but Gaius in this passage appears to be referring not only to such senatus consulta as had been passed under the empire, but to the senatus consulta generally as a source of law. It appears that the senate gradually came to be considered as the representative of the curiæ, and that its consulta, in many matters relating to administration, the care of religion, the ærarium, and the administration of the provinces, had the full effect of laws. It does not seem as if the Romans themselves had a very clear notion of the way in which the senate came to exercise the power of legislation; but they imagined that it arose of necessity with the increasing population of the state and the increase of public business. The senate thus became an active administrating body, and, as an easy consequence, that which it enacted (constituit) was observed, and this new source of law was termed Senatus Consultum. ('Dig.,' i., tit. 2.) It seems probable that the senate began to exercise the power of making senatus consulta after the passing of the Hortensia Lex, though it is not pretended that the Hortensia Lex, or any other Lex, gave this power to the senate. No senatus consulta are recorded as designated by the names of magistrates till the time of Augustus, a circumstance which seems to show that, whatever binding authority senatus consulta might have acquired under the Republic, they were not then viewed as laws properly so called, or as having the full effect of leges. But from the time of Augustus the titles of senatus consulta frequently occur; their names, like those of the leges, were derived from the consuls, as S. C. Velleianum, Pegasianum, Trebellianum, &c., or of the emperor who proposed them, as S. C. Claudianum, Neronianum, &c.; or they were said to be made "auctore Principe," or "ex auctoritate Principis." The expression applied to the senate so enacting was "censere." (Gaius, i. 17.) Special consulta were sometimes passed for the purpose of explaining or rendering effectual previous leges.

A new source of law was supplied by the Edicta of those magistrates who had the Jus Edicendi, but mainly by the prætors, the prætor urbanus and the prætor peregrinus. The edicts of the prætor urbanus were the most important. The body of law which was formed by the Edicta is accordingly sometimes called Jus Prætorium, which term however might be limited to the Edicta of the prætors, as opposed to those of the curule ædiles, the tribunes, censors, and pontifices. The name Jus Honorarium, as opposed to Jus Civile, comprehends the whole body of edictal law; and the name Honorarium was given to it, apparently because the Jus Edicendi was exercised only by those magistrates who had the Honores. Jus Civile, in its larger sense, comprehended all the law of any given nation; but the Jus Civile Romanorum, as opposed to the Honorarium, consisted of Leges, Plebiscita, Senatus Consulta, to which, under the empire, were added the Decreta Principum and the Auctoritas Prudentium. The Honorarium Jus was introduced for the purpose of aiding, supplying, and correcting the defects of the Jus Civile Romanorum in its limited sense. ('Dig.,' i., tit. i., s. 7.)

The historical origin of the edictal power is not known, but in the time of Cicero it had been so long exercised, and the Edicta had been so far formed into a regular system, that the study of the edictal law was a main part of the systematic study of the Roman law, and had taken the place of the Twelve Tables as an elementary branch of instruction. (Cic., 'Legg.,' ii. 4, 23; i. 5.) Servius Sulpicius, a distinguished jurist and a friend of Cicero, wrote two small books on the Edict, which were followed by a work of Ofilius, also on the Edict. Though the history of the edictal law, as already observed, cannot be traced, it thus appears that it had assumed a systematic form in the time of Cicero.

An Edictum was a rule promulgated by a magistratus when he entered on his office. It was committed to writing and put up in a public place. Its object was to declare by what rules the prætor would be governed in the administration of justice during the year of his office; and hence the Edictum was sometimes called Perpetuum or Annua Lex. An Edictum Repentinum applied only to the particular occasion on which it was made. All offices being annual, the rules of one magistratus were not binding on his successor, but his successor might adopt them into his own Edictum, and such adopted Edictum then became an Edictum Tralatitium. In this way numerous Edicta were adopted by one magistratus from the Edicta of his predecessors, and thus gradually a body of rules was formed and established, which experience had proved to be useful. Those Edicta which were of great importance are often referred to under the name of the magistratus who promulgated them, as the Edictum Carbonianum and others.

The general character of the Edict has been already stated. It is described in other words as "viva vox juris civilis," as a mode by which the rigid rules of the civil law were altered and extended to suit the altered circumstances of the times. The changes introduced by positive enactments into the Jus Privatum of the Roman law seem to have been very unimportant. It was not consistent with Roman notions to alter or change fundamental principles, and most of the legislation of the republican period had reference to the disputes between the two estates of the patricians and plebeians, and to other parts of the Jus Publicum. Accordingly it was left to the magistratus gradually to introduce the necessary changes into the Jus Privatum; but the process of doing this was in strict conformity to the principles of the old law. The Edict did not affect to make new law, but to adopt as law what custom had sanctioned, provided it was not against the Jus Civile; to give an action when a *bonâ fide* right existed, if the old law gave none; to protect a man in *bonâ fide* possession of property, without affecting to give him ownership, which the law alone could give him by virtue of usucapion; to aid parties by fictions, which however were always of such a kind that the thing which the fiction supposed, was that which would have given a strictly legal right. A great part of the efficacy of the Edict consisted in extending the remedies by action; and after the abolition of the Legis Actiones (with the exception of the Actio Damni Infecti, and of matters which belonged to the cognisance of the Centumviri) by the Lex Æbutia and two Leges Juliæ, the mode of proceeding in actions was settled by the formulæ of the Edicta. Still even here it seems probable that the prætors followed the analogy of the Legis Actiones and framed their formulæ accordingly. The Actiones given by the Edict were named after their author, as Publiciana, &c. The commentators on the Edicts were numerous under the early emperors. Labeo wrote at least four books on the Edictum of the Prætor Urbanus. Cœlius Sabinus commented on the Edict of the Curule Ædiles. In the time of Hadrian, Salvius Julianus, who had himself been prætor, compiled a work on the Edict, which was called Edictum Perpetuum. Nothing is known of the detail of this work, but it appears probable that it was designed to be a systematic exhibition of the whole body of edictal law, and as such it must have had considerable influence on the subsequent condition of jurisprudence. At what time the Edicta ceased to be made by the magistratus is a disputed point. The edictal power certainly existed under the empire, and even after the compilation of the Edictum Perpetuum of Julianus, but it must have been comparatively little exercised, as the practice of making new laws by Senatus Consulta prevailed under the Cæsars after the time of Augustus, and the Imperial Constitutions are mentioned as one of the recognised sources of law in the time of the Antonines. (Gaius, i. 5.)

With the establishment of the Imperial Constitution begins a new epoch in the Roman law. The leges of Augustus and those of his predecessor had some influence on the Jus Privatum, though they did not affect the fundamental principles of the Roman law. A Lex Julia came into operation, B.C. 18, but it is better known as the Lex Julia et Papia Poppæa, owing to the circumstance of another lex of the same import, but less severe in its provisions, being passed as a kind of supplement to it in the consulship of M. Papius Mutilus and Q. Poppæus Secundus, A.D. 9. This law had for its object the encouragement of marriage, but it contained a great variety of provisions: it is not known whether it was passed at the Comitia Centuriata or Tributa. A Lex Julia de Adulteriis, which also contained a chapter on the dos, is of uncertain date, but was probably passed before the former Lex Julia came into operation. Several Leges Juliæ Judiciariæ are also mentioned, which related both to Judicia Publica and Privata, and some of which may probably belong to the time of the dictator Cæsar.

The development of the Roman law in the Imperial period was little affected by direct legislation. New laws were made by Senatus Consulta, and subsequently by the Constitutiones Principum; but that which gives to this period its striking characteristic is the effect produced by the Responsa and the writings of the Roman jurists.

So long as the law of religion or the Jus Pontificium was blended with the Jus Civile, and the knowledge of both was confined to the patricians, jurisprudence was not a profession. But with the gradual separation of the Jus Civile and Pontificium, which was partly owing to the political changes by which the estate of the plebeians was put on a level with that of the patricians, there arose a class of persons who are designated as Jurisperiti, Jurisconsulti, Prudentes, and by other equivalent names. Of these jurisconsulti the earliest on record is Tiberius Coruncanius, a plebeian pontifex maximus, and consul B.C. 281: he is said to have been the first who professed to expound the law to any person who wanted his assistance (publice profiteri); he left no writings, but many of his Responsa were recorded. Tiberius Coruncanius had a long series of successors who cultivated the law, and whose responsa and writings were acknowledged and received as a part of the Jus Civile. The opinions of the jurisconsulti, whether given upon questions referred to them at their own houses, or with reference to matters in litigation, were accepted as the safest rule by which a judex or an arbiter could be guided. Accordingly, the mode of proceeding, as it is described by Pomponius, is perfectly simple; the judices in difficult cases took the opinion of the jurisconsulti, who gave it either orally or in writing. Augustus, it is said, gave the responsa of the jurists a different character. Before his time, their responsa, as such, could have no binding force, and they only indirectly obtained the character of law by being adopted by those who were empowered to pronounce a sentence. Augustus gave to certain jurists the respondendi jus, and declared that they should give their responsa "ex ejus auctoritate." In the time of Gaius (i., 7) the Responsa Prudentium had become a recognised source of law; but he observes that the responsa of those only were to be so considered who had received permission to make law (jura condere): and he adds that if they all agreed, their opinion was to be considered as law; if they disagreed, the judex might follow which opinion he pleased. The matter is thus left in some obscurity, and, for want of more precise information, we can only conjecture what was the precise way in which these licensed jurists under the empire were empowered to declare the law. It is however clear, both from the nature of the case and the statement of Gaius, that their functions were limited to exposition, or to the declaration of what was law in a given case, and that they had no power to make new rules of law as such; further, the licensed jurists must have formed a body or college, for otherwise it is not possible to conceive how the opinions of the majority could be ascertained on any given occasion.

The commencement of a more systematic exposition of law under the empire is indicated by the fact of the existence of two distinct sects or schools (scholæ) of jurists. These schools originated under Augustus, and the heads of each were respectively two distinguished jurists, Antisteus Labeo and Ateius Capito. But the schools took their names from other jurists. The followers of Capito's school, called Sabiniani, derived their name from Massurius Sabinus, a pupil of Capito, who lived under Tiberius and as late as the time of Nero: sometimes they were called Cassiani, from C. Cassius Longinus, another distinguished pupil of Capito. The other school was called Proculiani, from Proculus, a follower of Labeo. If we may take the authority of Pomponius, the characteristic difference of the two schools was this: Capito adhered to what was transmitted,—that is, he looked out for positive rules sanctioned by time; Labeo had more learning and a greater variety of knowledge, and accordingly he was ready to make innovations, for he had more confidence in himself; in other words, he was a philosophical more than an historical jurist. Gaius, who was himself a Sabinian, often refers to discrepancy of opinion between the two schools; but it is not easy to collect from the instances which he mentions what ought to be considered as their characteristic differences.

The jurisprudentes were not only authorised expounders of law, but they were most voluminous writers. Massurius Sabinus wrote three books Juris Civilis, which formed the model of subsequent writers. The commentators on the Edict were also very numerous, and among them are the names of Pomponius, Gaius, Ulpian, and Paulus. Gaius wrote an elementary work, which furnished the model of the Institutes of Justinian. Commentaries were also written on various Leges, and on the Senatus Consulta of the Imperial period; and finally, the writings of the earlier jurists themselves were commented on by their successors. The long series of writers to whom the name of classical jurists has been given, ends, about the time of Alexander Severus, with Modestinus, who was a pupil of Ulpian. Some idea may be formed of the vast mass of their writings from the titles of their works as preserved in the 'Digest,' and from the 'Index Florentinus;' but with the exception of the fragments which were selected by the compilers of that work, this great mass of juristical literature is nearly lost. [Justinian, in Biog. Div.]

Among the sources of law in the Imperial period are the Imperial Constitutiones. A Constitutio Principis is defined by Gaius (i. 5) to be "that which the imperator has constituted by Decretum, Edictum, or Epistola; nor has it ever been doubted that such constitutio has the force of law." As the emperor ultimately possessed all the sovereign power, he became the sole source of law. Under Augustus some Leges were passed, as already observed; and under his successors there were numerous Senatus Consulta. In the time of the Antonines there were both Senatus Consulta and Imperial constitutions, and the latter are referred to by Gaius as being of equally binding force with Senatus Consulta. After the time of Gaius, Constitutiones became more common, and few Senatus Consulta were passed. The Decretum of the emperor was a decision made in a matter of dispute which came before him either originally or by way of appeal. The Edict, or Leges Edictales, were formed by analogy to the Edicta of the magistrates, and were in effect Leges. Rescriptum was a general term which comprehended Epistolæ and Subscriptiones. The Rescripta were the answers of the emperor, made either to public functionaries or to individuals who consulted him. Sometimes Constitutio and Rescriptum are used as equivalent. (Gaius, ii. 120, 121.) Decreta and Rescripta, being decisions in particular cases, could not by their form have the force of leges; though when the determination made in a particular case was capable of a general application, it gradually obtained the force of law.

With the decline of Roman jurisprudence began the period of compilations, or codes, as they were termed. The earliest were the Codex Gregorianus and Hermogenianus, which are only known from fragments. The Codex Gregorianus, so far as we know it, began with constitutions of Sept. Severus, and ended with those of Diocletian and Maximian. The Codex Hermogenianus, so far as it is known, contained constitutions also of Diocletian and Maximian, and perhaps some of a later date. Though these codes were mere private collections, they apparently came to be considered as authority, and the codes of Theodosius and Justinian were formed on their model.

The code of Theodosius was compiled under the authority of Theodosius II., emperor of the East. It was promulgated as law in the Eastern Empire, A.D. 438; and in the same year it was confirmed as law in the Western Empire by Valentinian III. and the Roman senate. This code consists of sixteen books, the greater part of which, as well as of the Novellæ, subsequently promulgated by Theodosius II., are extant in their original form. The commission who compiled it were instructed to collect all the Edicta and Leges Generales from the time of Constantine, and to follow the Codex Gregorianus and Hermogenianus as their model. Though the arrangement of the subsequent code of Justinian differs considerably from that of Theodosius, it is clear from a comparison of them that the compilers of Justinian's code were greatly aided by that of his imperial predecessor. The valuable edition of the Theodosian Code, by J. Gothofredus (6 vols. fol., Lugd., 1665), re-edited by Ritter, Leipzig, 1736–1745, contains the first five books and the beginning of the sixth, only as they are epitomised in the Breviarium; and this is also the case with the edition of the 'Jus Civile Antejustinianeum,' published at Berlin in 1815. But recent discoveries have greatly contributed to improve the first five books. The most recent edition of the 'Jus Civile Antejustinianeum' is that of Bonn, 1835 and 1837.

The legislation of Justinian is treated of under Justinian's Legislation.

There are numerous works on the history of the Roman law, but it will be sufficient to mention a few of the more recent, as they contain references to all the earlier works: *Lehrbuch der Geschichte des Römischen Rechts*, by Hugo, of which there are numerous editions; *Geschichte des Römischen Privatrechts*, by Zimmern; *Geschichte des Römischen Rechts*, by F. Walter, 1840; and for the later history of the Roman law, *Geschichte des Römischen Rechts im Mittelalter*, by Savigny.

ROMAN SCHOOL OF PAINTING. [Painting.]

ROMANCE originally signified any composition in the romance language, or dialects which superseded the Latin after the fall of the Western Empire. [Romance Language.] As however, in course of time, the Trouveres of North France composed a number of poems containing fictitious narratives of war and love, and their lays became popular all over France and in the neighbouring countries, the name of romance was more particularly applied to all compositions, whether in verse or prose, in any language, which treated of marvellous or uncommon incidents, and the name has been retained to this day in several European languages to signify a fictitious narrative. The Italians and French call a novel "un romanzo," "un roman." But the French call an historical ballad "une romance," in the feminine gender. The distinction between romance and the modern novel is shown under Novel. The appellation romance in a narrower sense is applied to those compositions which refer to the ages of chivalry, either real or supposed. [Chivalry.]

The oldest romances in this latter sense appear to have been legendary stories concerning Arthur and the Knights of the Round Table, and they were of English origin; but the original narratives, if they ever existed in writing, which is doubtful, are lost. The earliest romantic legends which have come down to us are of the 12th century: Geoffrey of Monmouth's Latin Chronicle of England; Turpin's Latin Chronicle of France; Wace's 'Le Brut,' a metrical romance concerning the fabulous history of England, in Norman French; 'Le Roman du Rou,' by the same writer, concerning Rollo and his successors; and 'I Reali di Francia,' in Italian prose. To these may be added the Latin romance of Gualtieri, found in the Chronicle of La Novalesa, which relates to the wars of Attila; next in order of date comes Guido della Colonna's 'War of Troy,' and Mathew Paris's account of the Round Table. The 'Roman de la Rose' was written under St. Louis of France. At that time chivalry was established over all Europe, and the writers of romance introduced the customs and manners of chivalry into their narratives of events, real or supposed, long antecedent to the existence of chivalry.

The vast subject of romantic literature, in its general and more extended sense, may be divided into the following branches:—1, Romantic ballads and traditional songs, which appear to be the oldest form, and which have existed among most nations in their primitive state. The songs of the ancient bards, and those concerning Arminius, which are mentioned by Tacitus ('Annal.' ii. 88, and 'German.', 2); the German Niebelungen; the poems of Antar, and others before the æra of Mohammed; the song of Roland, mentioned by the chroniclers of Charlemagne; and the old Spanish romantic ballads, all belong to this class. M. de Tressan collected several fragments among the mountaineers of the Pyrenees, which seem to belong to Roland's 'Cantilena,' or war song. 2, The narrative romances of chivalry concerning the deeds of Arthur and the peers of the Round Table. 3, The romances concerning the supposed wars of Charlemagne against the Saracens. 4, The Spanish and Portuguese romances concerning the fabulous exploits of Amadis and Palmerin. 5, The classic romances concerning Jason, Hercules, Alexander, those heroes having been transformed into knights of chivalry. 6, The epic romances of the Italians in the 15th and 16th centuries. [Pulci, in Biog. Div.] 7, The spiritual or religious romances concerning the miracles of saints and the death of martyrs, such as the 'Contes dévots' of the French, the 'Golden Legend,' &c. 8, The pastoral romance, which Cervantes ridiculed, and which afterwards gave rise in the 17th century to the interminable and dull romances of La Calprenède, Madame de Scudery, and others, in which perfection of beauty and pure spiritual love are the chief ingredients. 9, The comic romances, which were written chiefly as parodies of the heroic and chivalrous romances. Such were those of Rabelais, Cervantes, Mendoza, and Scarron. 10, The political romances, such as Télémaque, Sethos, &c. 11, The supernatural romance, like the 'Castle of Otranto,' 'The Old English Baron;' in which may be included those of Mrs. Radcliffe, where a supernatural impression is given by inadequate natural causes. 12, Lastly comes the modern novel, which forms a distinct species, as it does not deal in the marvellous and supernatural, but represents men conformably to the manners of the age in which they lived.

ROMANCE LANGUAGE ('Langue Romane' or 'Romande,' in French) is the name given to a kind of bastard Latin, which came into common use in Western Europe after the fall of the Roman Empire, among the populations formerly subject to Rome, while the Northern conquerors, the Goths, Franks, Burgundians, Langobards, &c., spoke their own language or dialects, which are called by chroniclers of the times "lingua Teutonica," or "Teutisca." The conquered people were called by the general name of Romans, from whence came the name of the language, which was also called "vulgaris." In course of time however the conquerors adopted the language of the conquered, who being more instructed, furnished most of the priests and scholars of the age. But the language thus adopted by both the conquering and the conquered races, although essentially formed of Latin elements, differed according to the various localities and the greater or lesser degree of admixture of the northern people with the Roman population. For instance, king Dagobert in the 7th century published a statute, styled, "Lex Alamannorum," for the use of the German tribes who had crossed the Rhine, the language of which differs from that of the "Lex Ripuariorum," which the same king published for the use of the people situated between the Lower Rhine and the Mosa, who were mostly of old Roman extraction. The former employs the *ille* as an article before substantives, in imitation of the articles *sa* and *der* used by the Goths and Franks in their own language; but the Lex Ripuaria does not employ *ille* for the same purpose. In the old charters of Italy and Spain of the 8th and 9th centuries, we find *ille* and *ipse* employed likewise as articles, *ipsa ecclesia*, *illa alia*, *illas casas*, *illa strada*, *illo rio*, &c.; but these charters are not so old by a century or two as the Franco-Latin documents, in which those pronouns are introduced for a similar purpose. The oldest documents in the 'España Sagrada' in which the *ille* appears as an article is A.D. 775; and the oldest of those of Italy quoted by Muratori are of the years 713 and 736.

Of the various dialects thus formed, that of the south of France, called afterwards Langue d'Oc, became a refined language sooner than the others, and retained its superiority from the 10th to the 13th century, when the Italian, Portuguese, and Spanish languages assumed a regular grammatical and literary form, which they have retained; whilst the romance of the south of France has gradually fallen into disuse, having given way to the Northern French Langue d'Oil or d'Oui. The latter appears to have originally differed little from the Langue d'Oc, but it gradually changed its terminations, and assumed other peculiarities of form, which have been retained by the modern French. It is demonstrated by Raynouard that the inhabitants of Northern France in the 9th century spoke the same language as those of the south. The text of the oath taken at Strasburg in the year 842, by Louis, called the Germanic, before the French people, would alone be a sufficient proof of this. The text of this curious document is as follows:—"Pro Deo amur et pro Christian poplo, et nostro commun salvament, dist di en avant, in quant Deus savir et podir me dunat, si salvara jeo cist meon fradre Karlo, et in adjudha, et in cadhuna cosa, si cum om per dreit son fradre salvar dist, in o quid il mi altre si fazet, et ab Ludher nul plaid nunquam prindrai, qui meon vol cist meon fradre Karle in damno sit." (Roquefort, 'Glossaire de la Langue Romane,' Paris, 1808, Introduction.)

The gradual process by which the corrupt Latin spoken in the provinces of Western and Southern Europe in the 6th, 7th and 8th centuries was transformed into the Romance languages of the 9th and 10th centuries, is very clearly exhibited by Raynouard, in his 'Elémens de la Grammaire de la Langue Romane avant l'an 1000.' The Latin cases had become neglected or confused, and to supply their place the prepositions *de* served to denote the genitive and *ad* the dative. The next step was to cut off the final syllable of the noun, and so to make it indeclinable. Thus the accusative abbatem became abbat; majestatem, majestat; ardentem, ardent; amantem, amant; and so forth. The accusatives in *ionem* were reduced to *ion*, religionem, religion, &c. When the suppression of the Latin termination left two harsh-sounding consonants at the end of the word, a euphonic vowel was added, "arbitr-um," "ar-bitr-e." The pronouns *ille* and *ipse* had been used in the corrupt Latin as auxiliary to substantives: "Dono illas vineas quomodo ille rivulus currit;" "Illa medietate de ipsa porcione," &c. From *ille* so used originated the romance articles *el*, *lo*, *la*, and from *ipse* the demonstrative pronouns, *is*, *so* or *su*, and *sa*, which the Sardinian dialect has retained to this day as an article. These articles were declined with the prepositions *de* and *a*. "Ego Hugo della Roca;" "Fossatum de la vite;" "Villam nostram quæ vocatur al la Carbaria," &c. These and other examples taken from documents of the 9th century show the introduction of articles even in the written language which affected to preserve in some degree the Latin form; the change must have been more rapid and complete in the spoken or popular idiom. Other changes took place in the pronouns and the verbs, for which we refer to Raynouard's 'Elémens.' The use of the auxiliary verb *aver*, "habere," already existed in the Latin, in a certain form: "De Cæsare satis hoc tempore dictum habebo" (Cicero, 'Philip. V.' 28); "Si habes jam statutum quod tibi agendum putes" ('Epist. ad Famil.', iv. 2). The Latin also used the auxiliary "esse" in some tenses of the passive. The Romance language only made the use of these auxiliaries more general.

After A.D. 1000 the Romance language may be considered as having become duly formed, and the age of the Troubadours began. William, count of Poictiers, is one of the earliest whose works have been preserved. In the 12th century the institution of the Courts of Love was established. That century was the brilliant age of Romance poetry, and in the same Wace wrote in North or Norman French his 'Roman du Rou.' In the 13th century the war and massacre of the Albigenses, and the establishment of the Inquisition, frightened away many of the adepts of "la gaya ciencia;" and afterwards several other events, such as the accession of the house of Anjou or Provence to the throne of Naples, and the encroachments of the Northern French, contributed to the decline of the troubadour poetry, and at the same time of the Romance language. The Italian or Tuscan rose upon its decay. When Dante appeared, the decline had already begun, and it was completed during the first part of the 14th century. (Raynouard, 'Choix de Poesies Originales des Troubadours;' Professor Diez, 'Leben und Werke der Troubadours,' Zwickau, 1829.) In the 15th century king René made some attempts at reviving the poetry of the Langue d'Oc, but the race of the Troubadours was now extinct, and the only result of his endeavours was the collecting and compiling the lives of the old Troubadours by the monk of the isles of Hyeres, "Le Monge des Isles d'Or." In Eastern Spain also the Inquisition destroyed many manuscripts in the Limosin or Valencian language, as being suspected of containing heresy. In 1434 the library of the Marquis de Villena at Barcelona was burnt on suspicion of containing sorcery. (Ferrario, 'Storia ed Analisi degli antichi Romanzi,' &c.)

Various political and social circumstances had contributed to give to the Langue d'Oc that early refinement in an age of comparative ignorance and barbarism which is still a matter of surprise to philologists and historical inquirers. The provinces of Southern France had not, like Italy and the northern parts of France, been overrun by a succession of barbarians; they had not been exposed to the ravages of the Slavonians, the Huns, and the Danes. The Burgundians and the Visigoths, who had settled there nearly about the same time, were more civilised than the other German races; they amalgamated gradually and quietly with the old inhabitants, and they applied themselves to agricultural pursuits, which a fertile soil and a happy climate rendered pleasant and productive. The country suffered no subsequent invasion from the northern tribes, and the victory of Charles Martel in the plains of Tours arrested the advance of the Saracens from the west. Southern France was, it is true, subjugated by the Franks, who had occupied the countries north of the Loire, but the Franks had by that time formed themselves into a regular monarchy under Pepin and Charlemagne, and were no longer unruly barbarians. During the decline and imbecility of the latter princes of the Carlovingian dynasty, Southern France became a separate and independent state, of which duke Bozon, an active and vigorous man, became monarch, and the kingdom of Arles or Provence extended over the whole south of France. The descendants of Bozon retained their sovereignty for more than two hundred years; and when the male line ended in 1092, in the person of Count Gillibert, his states became the dowry of his daughters, of whom the elder, Douce, heiress of Provence, was married in the year 1112 to Raymond Berenger, count of Barcelona, and her sister Stephanie married the count of Toulouse. A treaty, concluded in 1125, between the counts of Barcelona and Toulouse, fixed the division of the states of Gillibert between them. Another powerful baron, the count of Poitiers, became duke of Aquitaine or Guyenne, which afterwards came by marriage into the possession of Henry II. of England. These three states, Barcelona, Toulouse, and Guienne included the whole country in which the Langue d'Oc was spoken. The union of Provence with Catalonia introduced into the former country a taste for poetry and chivalry, which was fostered in Spain by the Moors. The maritime towns of Catalonia and Provence carried on a lucrative trade all over the Mediterranean, and Catalonian armaments took an active part in the Eastern wars between the Greeks, the Normans, and the Saracens. All these circumstances contributed to refine the manners of the people as well as their language, and the singular institution of the Courts of Love gave a peculiar turn to their poetry. [TROUBADOURS.]

The Langue d'Oil, or Northern French, also called sometimes Norman French, having become the language of the court and capital of the kingdom of France, gradually encroached upon the Langue d'Oc, as the various provinces south of the Loire became incorporated with the monarchy. From the 13th century downwards, the edicts and ordinances of the French kings being issued in the Langue d'Oil, were forwarded, either in the original or translated into Latin, to the provinces of the south. The writers of Northern France, the Trouvères, refined their own language, and found encouragement at court, which was not extended to the writers in the Langue d'Oc. Ronsard, who was a native of the south, in his 'Abregé de l'Art Poétique,' complains of this : "Now that our France is all subject to one king, we are obliged, if we wish to attain honour or fame, to speak his language, else our works, however honourable and perfect, would be thought little of, or might perhaps be altogether despised and neglected." With the invention of printing, copies of the works in the Langue d'Oil were speedily multiplied, while those of the Troubadours remained mostly in manuscripts, confined to a few libraries. In the 16th century it was enacted that all public acts and deeds should be written in French. The Langue d'Oc, being thus restricted to the mere purposes of a domestic idiom, degenerated into various patois or dialects. Still there appeared, here and there, in the 17th and 18th centuries, several native poets who wrote with spirit and humour in their respective patois, such as Lesage, a Languedocian, whose burlesque and frequently licentious poems were published at Montpelier: 'Les Folies de le Sage,' 1650; Ader, 'Lou Gentilhomme Gascoun,' Toulouse, 1610, and 'Lou Catounet Gascon,' 1611; a version of Homer's 'Batrachomyomachia,' in Gascon, 'La Granoul-Batromachio,' Toulouse, 1664; 'La Pastourale (a comedy in 4 acts) deu Paysan que cerque mestié a son bila,' in the dialect of Béarn by Foudeville de Lescar, Pau, 1767; 'L'Embarras de la Fieiro de Beaucaire,' by Michel, Amsterdam, 1700; 'Actes du Synode de la Sainte Reformation,' Montpelier, 1599, a satire against the Calvinists, by Reboul, a witty but profligate adventurer, who was at last executed at Rome, under pope Paul V., in September, 1611, in consequence of his undiscriminating satirical propensity; 'Lou Banquet,' par Augié, Gaillard, Paris, 1583; the 'Jardin deys Musos Provençales,' Aix, 1628; &c.

In Spain the Latin language became corrupted, though perhaps less rapidly and at a later date than in Italy and France, which is proved by the fact that during the 8th and 9th centuries masters were procured from the Peninsula to teach that language in Italy. It is another evidence of this, that till the beginning of the 12th century, Latin, though corrupt, was the only language used among the Christian population of the Peninsula, not only in the acts of the cortes and councils, but also in the municipal fueros, the public edicts, diplomas, testaments, and the writings of authors. It was also the language of the tribunals, until San Fernando, about the middle of the 13th century, caused the 'Liber Judicum' to be translated into the vulgar tongue.

The corrupt Latin of Spain gave rise to the Catalonian and Valencian, the old Portuguese or Galician, and the Castilian or modern Spanish. The last two, and especially the Castilian, received a considerable admixture of Arabic words (said to be about 2000 in the Spanish language), from which the Catalonian remained comparatively free. The process of corruption of the Latin into Romance was the same as in France and Italy, and may be traced even in the writings of the clergy, who professed to use the literary language of the country. Elipando, bishop of Toledo, a man of learning for the time, who strongly opposed the introduction into Spain of the tenets of the supremacy and infallibility of the Roman see, writes to Felix, bishop of Urgel, in the following style: "Domino Felice, sciente vos reddo quia vestro scripto accepi . . . . direxi vobis scriptum parvum de fratre Militane . . . . ego vero direxi epistolam tuam ad Cordoba," &c.

It is impossible to fix the epochs of the origin of the various languages of the Spanish peninsula. The Catalonian and Galician or old Portuguese appear to be the oldest. The Castilian, notwithstanding the assertion of Bouterwek to the contrary, was not formed in the 11th century; its oldest existing monument, the poem of 'El Cid,' is not older than the year 1200. Previous to the 12th century the Galician, or old Portuguese, appears to have prevailed in all western Spain. An old manuscript Cancioneiro in this dialect, belonging to the library of the Royal College of the Nobles at Lisbon, of which Sir Charles Stuart obtained a copy, which he communicated to Raynouard, speaks of the Galician dialect as being spoken in Galicia and in Portugal, as far south as Coimbra, in the 10th and 11th centuries, after which the Portuguese grew into a separate and polished dialect, which was much in use for poetry among Galicians and Castilians as well as Portuguese. (Raynouard, 'Grammaire Comparée,' Discours Préliminaire.)

In the 'Elucidação das Palavras, Termos, e Frases que em Portugal antigamente se usárão,' 2 vols. fol., Lisbon, 1798, are other specimens of old Portuguese or Galician compositions. The original text of the 'Amadis de Gaula,' by Vasco de Lobeira, which is lost, was written in the same language.

The Catalonian dialect became early a literary language, and as such subject to fixed grammatical rules; it has its grammars and dictionaries, a great number of printed books, and a still greater number in manuscript. It had its historians; among others an anonymous historian of Catalonia, mentioned by Zurita in his 'Chronicas de Aragon;' Bernard de Sclot, who lived in the 13th century, and wrote a history of the principality of Catalonia and of the Aragonese kings subsequent to the junction of the two states; and King Jayme I. of Aragon, who wrote an account of his own reign, which has been published under the following title: 'Chronica o Commentari del gloriosissim e invictissim Rey Jaume Rey d'Aragó de Mallorques e de Valencia, Compte de Barcelona e de Urgell, e de Muntpellier, escrita per aquell en sa lengua natural, e treta del Archiu del molt magnifich Rational de la insigne Ciutat de Valencia, hon estava custodita,' Valencia, 1557. King Jayme also wrote a book 'de la Saviesa' 'on wisdom,' quoted by Nicolas Antonio, in his 'Bibliotheca Vetus.' The Catalonian is rich in poetry, which was introduced into the Peninsula by the Troubadours of Provence and Languedoc. Alonso II. of Aragon, in the 12th century, is numbered among its poets, as well as Guillermo de Berguedan, a Catalonian noble, who lived in the following century, and some of whose verses are preserved in a manuscript in the Vatican library. Mosen Pero March, Jacme March, Mosen Jorde, Mosen Febler, and Ausias March of Valencia, rank also among the Catalonian, Aragonese, and Valencian Troubadours. [TROUBADOURS.]

The languages of Aragon and Valencia, in the time of the Aragonese monarchy, may be considered as one and the same with the Catalonian. It is worthy of remark, that at the end of the 13th century, when the Castilian language had already gained the preponderance in a great part of Spain, we find a controversial conference between the Jews of Granada and some Christian missionaries from Castile, carried on in the Catalonian language, which appears to have been vernacular at Granada. ('Memoirs of the Royal Academy of Barcelona,' i., p. 615.) In the same Memoirs (p. 613) it is stated that the bishop of Orense, having been requested to examine what analogy there might be between the vulgar Galician and the Catalonian, answered, that there were in both, not only nouns, verbs, and other parts of speech quite identical, but also entire phrases. And Terreros (in his 'Paleography') and others have stated, that the language of Asturias is the same as that of Galicia, bating the difference of pronunciation.

The Catalonian, observes Raynouard, is the living language which most resembles the old Romance of the Troubadours, and that of the Valdenses of Pignerol in Piedmont is the next. The following are among the shades of difference between the Catalonian and the Romance:—1. The Romance substantives and adjectives ending in *an*, *en*, *in*, and *un*, add in Catalonian the euphonic final vowel *y*; *affan*, *affany*, *estran*, *estrany*, &c. The plural feminine in *as* is changed into *es*. The Catalonian often changes the *s* into an *x*; *axi*, *puix*: it doubles the *l* at the beginning and at the end of words; *aquell*, *lloch*, *lluny*; it sometimes changes the *e* into an *i*, especially of the Romance participles in *ent*; *dormint*, *servint*, *fugint*, *premint*: it adds a final *u* to some inflections of the verbs, &c. The Catalonian has retained the affixes of the Romance, of which the following are specimens taken from the poems of Ausias March, the Valencian Troubadour:

> Mottra *m* la llum de vera esperança,
> Be *ns* mostra Deu lo mon que vol finir
> Tot mon parlar als que no *us* auran vista,
> No solament los leigs qui *t* venen contra.

The popular patois or dialects of the south of France, after being long neglected, have of late years attracted the attention of philologists. Colomb de Batines has given an account of the patois of Dauphiné; Sainte Beuve inserted a notice in the 'Revue des Deux Mondes,' vol. x., 1837, of the poems of Jasmin, the barber poet of Agen; a 'Recueil de Poésies Béarnoises,' was published at Pau in 1827. (The Bearnese dialect is a Romance and not a Basque dialect, and resembles the Gascon.) The dialect of Gascony has been illustrated by the Viscount de Métivier: 'De l'Agriculture et du Défrichement des Landes,' Bordeaux, 1839; and also by Du Mege: 'Statistique des Départemens des Pyrénées.' The Languedocian boasts of two graceful poets, brothers: 'Poésias Patouesas de P. A. et Cyr. Rigaud,' Moupeyé, 1806; 'Mêlanges sur les Langues, Dialectes, et Patois,' Paris, 1831; Beronie, 'Dictionnaire Patois,' Tulle, 1820; the poems of Verdié, a self-instructed artisan of Bordeaux, who died in 1820—whose works, full of humour and nature, are unknown beyond the precincts of his native town; an imitation of the fables of Lafontaine, in the dialect of Limousin, by J. Fouçaud, 1835; Brunet, 'Notices et Extraits de quelques ouvrages écrits en Patois du Midi de la France,' Paris, 1840; Millin, 'Essai sur la Langue et la Littérature Provençale,' Paris, 1811; J. Champollion Figeac, 'Nouvelles Recherches sur les Patois ou Idiomes vulgaires de la France, et en particulier sur ceux du Département de l'Isère, suivies d'un Essai sur la Littérature Dauphinoise, et d'un Appendix contenant des pièces en vers et en prose peu connues, et un Vocabulaire,' Paris, 1809; Grinet, 'Vocabulaire Limousin,' a dialect which resembles those of Franche Comté and Western Switzerland.

With regard to the ancient Langue d'Oc, or Langue Romane, the most refined of all the southern dialects, but which may be considered now as a dead language, it was illustrated in the last century, in Italy, by Bastero, 'La Crusca Provenzale;' and in France, by L'Abbé Millot, 'Histoire Littéraire des Troubadours,' who compiled his work from the voluminous manuscript folios of M. de Sainte Palaye. In the present century, Raynouard has been the most industrious and most successful investigator of the Romance language and literature. His 'Lexique Roman, ou Dict. de la Langue des Troubadours,' was published in 6 vols. 8vo, Par. 1836–44. M. Honnorat has published a 'Dictionnaire Provencal-Française,' or Dictionary of the Langue d'Oc, ancient and modern, 2 vols. 4to, Paris, 1846–49; and G. F. Burguy a 'Grammaire de la Langue d'Oil, ou grammaires des dialectes Français aux XII. et XIII. siècles,' accompanied by a glossary, 2 vols., Berlin, 1853–54. Other valuable works have also appeared, either written or edited by Mahn, Villemarque, &c.

In Italy, the dialect of the valleys of Pignerol, or of the Valdenses, has most affinity to the old Romance. The Piedmontese, which is a written language, and is spoken by all classes of people, bears also considerable affinity to the modern Romance dialects of Southern France, and we have heard it stated that natives of Languedoc can understand those of Piedmont with ease. Dr. Pipino published a Piedmontese grammar, Turin, 1783; and Ponza published, in 1827-8, a Dictionary, Piedmontese and Italian. The language of Nice is also a corrupt dialect of the Langue d'Oc.

With regard to the other North Italian or Lombard dialects, they differ more or less from the old Romance language, though they had a common and perhaps coeval origin with it, and resemble it more than the Italian or Tuscan. The Langue d'Oc, having been formed chiefly from a corrupt and provincial Latin, as well as the dialects of Italy, reduced its materials to a regular form sooner than they; and having become a polished and literary language, the Italians in their turn borrowed at second-hand from it. Raynouard, in his 'Grammaire Comparée,' observes that the dialect of Ferrara is one of those which has retained more completely the forms of the Romance with the least admixture. That of Bergamo comes perhaps the next in affinity: it often changes the *e* into *o*; for example, instead of *el*, *del* (Romance), it has made *ol*, *dol*. The dialects of Bologna and Mantua abound with contractions and aphæreses, which render them very harsh; they have taken away the *t* of the Romance terminations in *at*, *it*, *ut*. The Milanese has a broad pronunciation, and many double vowels, changing into *aa*, *ii*, and *uu*, the Romance terminations in *at*, *it*, and *ut*; *veritaa*, *servii*, *avuu*, &c.; it also changes *re* into *er*; *noster*, *sepolcher*, for the Romance *nostre*, *sepolchre*. The dialects of the Venetian territory, with the exception of that of Friuli, are more remote from the Romance in their formation, as are likewise still more so the dialects south of the Apennines, or of Southern Italy. We cannot here enlarge upon the multifarious subject of the Italian dialects, but must refer the inquisitive reader to their grammars, vocabularies, and other works.

The dialects of Western Switzerland, Vaud, Neuchâtel, Geneva, part of Freyburg and Lower Valais, and also of Savoy, have retained to this day the name of patois Romand, or Langue Romande. Western Switzerland, as far as the Aar, was occupied in the decline of the Roman empire by the Burgundians, a less rude tribe than the Alemanni, who settled in Eastern Switzerland. The Burgundians shared the land with the native population of Roman, Helvetian, or Allobrogic race; they applied themselves to agriculture, and soon constituted themselves into a well regulated and orderly monarchy. They gradually adopted the provincial Latin which they found in use in the country, and from the corruption of which several Romance dialects were formed, which resembled those of the south of France that were formed through a similar process. Some of the dialects of Western Switzerland approximate in their inflexions to the Northern French, or Langue d'Oïl, whilst others, like that of Gruyère in the canton of Freyburg, bear more affinity to the Romance of the south, and consequently to the Italian. Specimens of both are contained in Stalder's 'Dialektologie,' and also in the collection of Ranz des Vaches, both in German and Romance, 'Sammlung von Schweizer Kuhreihen und Volksliedern,' Bern, 1818. To this day, Switzerland is divided, by language, races, and habits, into German and Romande, and the Germans call the latter by the general name of Welschland.

In the country of the Grisons, or ancient Rhæti, one half of the people speak a language called Rumonsch, which is an Italian dialect of very ancient formation, supposed by some to be derived from the language of the Etruscans, who emigrated to those valleys about 600 years B.C.; but this is a mere conjecture. The Rumonsch is a written language, and books have been published in it. MSS. eight or nine centuries old existed at the end of the last century, and perhaps some still exist in the convent of Disentis. The dialect of the Engadina, or valley of the Inn, is called Ladin: it has still greater affinity to the Italian or Lombard dialects. Specimens of Rumonsch and Ladin are found in the Appendix to Vieusseux's 'History of Switzerland,' published by the Society for the Diffusion of Useful Knowledge. Raynouard observes that the Rumonsch has the affixes and other essential forms of the Romance language, though it is disfigured by an admixture of Northern or Teutonic orthography and pronunciation. It often adds a *g* to the end of words; *filg*, *volg*, *haig*, *testamaing*, for the Romance *fil*, *vol*, *hai*, *testament*.

If we take the appellation of Romance language in its most extended sense, all the languages and dialects of Western Europe, that is to say, of Italy, Western Switzerland, the Grisons, France, and Spain, may be called Romance, being derived essentially from the Roman or Latin, and having been formed after the fall of the Western Empire. The Basque and the Armorican or language of Lower Britanny belong to a different family. The Walloon of Lège and the Valachian are also Romance languages. The Valachian resembles the others, though less perhaps in its grammatical forms than in the etymology of the words. Raynouard shows the analogy existing between them all in their grammatical construction and etymology in his 'Grammaire Comparée des Langues de l'Europe Latine.' But if we take the word Romance in its more restricted sense, as having been especially applied to the language of the troubadours, or Langue d'Oc, we must consider it as confined to the south of France, and the eastern provinces of Spain as far as Murcia, and it is there that we find its legitimate offspring in the languages of Catalonia, Valencia, and Majorca, and in the Languedocian, Provencal, and Valdenses dialects.

Raynouard at the conclusion of his 'Grammaire Comparée' of the languages of Latin or Roman Europe, enumerates twenty-three special characteristics in the construction of the Romance language, most of which occur also in the other languages and dialects of Western and Southern Europe, which he styles 'Neo-Latin.' 1. The use of articles to determine the cases, instead of their being designated by the termination of the word as in Latin. This characteristic is found in all the modern languages derived from the Latin. 2 and 3. Relate to the terminations of words, especially nouns, of which Raynouard gives comparative tables in the various languages. 4. Is peculiar to the old Romance, but existed also in the Northern French till the 14th century. It consists in placing an *s* at the end of substantives in the singular, when they stand as subjects; the absence of the *s* shows they were used in the objective case. In the plural it was the reverse, the absence of the *s* designated the nominative. The Northern French dropped the *s* generally in the singular, and gave it to the plural without distinction. 5. Refers to other terminations employed by the old Romance, especially in proper names, to distinguish the subject from the object. 6. Concerns the gender of the adjectives. 7. Concerns the degrees of comparison. 8. Is on the Romance affixes representing personal pronouns, *ous*, *os*, *m*, *x*, which are also met with in the old French and old Spanish, and also in some rustic dialects of France, in the Catalonian, and in some north Italian dialects. 9. The pronoun *altre* is an expletive added to the personal pronoun. This has been adopted by all the Neo-Latin languages of Europe; *vous autres*, *vos otros*, *vos outros*, *voi altri*, &c. 10. Relative pronouns *qui*, *que*, *lo qual*. 11. The indefinite pronoun *om*, derived from the Latin *homo*, which the French has retained in *on*. The Spanish and Portuguese, which formerly employed *ome* in the same sense, have since substituted *se*, and the Italians *si*. 12. Concerns the use in the conjugations of the auxiliary verbs *aver*, *ester*, and *estar*, which have been adopted, with some modifications, by all the other Romance languages. 13 and 14. Concern the formation of the future and the conditional. 15. Concerns the participles in *ut*, of which the French has made *u*. 16. Concerns the double formation of participles of the same verb, such as *rot* and *romput*, *defet* and *defendat*, *eleit* and *elegit*, &c. 17. The compound passive formed of the auxiliary *esser* and the participle past, which has been substituted in all cases for the Latin simple passive form. 18. Concerns the verbs used impersonally. 19. The infinitive with the negative, used as an imperative. The Italian has retained it: "Non parlare:" speak not. 20. The various uses of the conjunction *que*. 21. Formation of adverbs from the feminine adjective by adding the affix *ment*, which has been adopted by all the other languages derived from the Latin. 22. The expletives *pas*, *mica*, *gaire*, &c., added to the negative particle to give it greater emphasis. This form is retained by the French in *pas*, and by the Italians in *mica* and *guari*. 23. Concerns the appellations *Romans*, *Romance*, *Roumonch*, *Romanza*, which were used by the old French, Italian, Spanish, and Portuguese writers to designate their respective idioms; an appellation which serves to show their common origin. The most recent general dictionary of the Romance language is the 'Lexicon Etymologicum linguarum Romanarum, Italicæ, Hispaniæ, Gallicæ, &c.,' of F. Diez, Bonn, 1853.

ROMANESQUE ARCHITECTURE is that style of round-arched architecture which (with local or national peculiarities) prevailed through a large part of Europe during the 11th and 12th centuries. Under BYZANTINE ARCHITECTURE, it was pointed out how the architecture of the ancient Romans diverged in the hands of their barbaric successors into a two-fold form: the older becoming moulded, in the Eastern Empire, into that known as the Byzantine style, and which was the parent of the subsequent ecclesiastical architecture of the east of Europe; and the later, that which in the Western Empire became in the hands of the ecclesiastical architects what is now known as Romanesque, and which, as was shown under GOTHIC ARCHITECTURE, became in its ultimate development, Pointed Gothic. Romanesque architecture then, both in time and place, stands between the classic Roman and the Pointed Gothic; and is, in fact, the link which connects the one with the other.

Until the final separation of the Western from the Eastern Empire, the Byzantine type was in the ascendant; but in the West such architecture as existed was rather a debased Roman, than an independent or derived style. Yet traces of the Romanesque appeared at a comparatively early date. Its germ was certainly visible in the 6th or 7th century; but this was followed by a long interval of quiescence. Some have fancied that the revival is due to the Lombard kings, and have consequently termed the style itself Lombardic. But the revivification of architecture does not seem to be really traceable farther back than the 10th century; the development of the style belongs to the 11th century, and its highest perfection to the 12th, when its obvious insufficiency to meet the growing requirements of the age led to the introduction of the feature which caused it to merge into what is usually regarded as a totally different style. Nor, as we have intimated, can it be especially assigned to any particular locality. Lombardy may have been the cradle of the actual Romanesque, but it soon spread through other parts of Italy; along the Rhine, in Germany and Switzerland; throughout France, and by way of Normandy to England. The styles of these countries are indeed frequently treated as though not only different but unconnected, but in principle they are essentially the same; the differences consisting of those local and national features which are due to the character of the inhabitants, and the physical (or geological) peculiarities of the country, and which are always found unless the inventive faculties are controlled by rigid ecclesiastical or professional precedents. We may say, however, that as the birthplace of the style was Italy, it was there that it retained most decidedly the resemblance to its original, the divergence from the classic type becoming more marked in proportion to its distance in place as well as time from its source. And whilst in other countries the Romanesque merged in the 13th century into Pointed Gothic, in Italy it maintained itself as the prevalent style till the advent of the Renaissance.

We shall here treat of Romanesque architecture generally: the peculiar forms it assumed in our own country, first in a very rude shape in the Anglo-Saxon, and afterwards in a more developed and artistic condition as the Anglo-Norman style, are noticed under Norman Architecture, and Saxon Architecture, to which articles we refer for many of the details necessarily omitted here, and which are in a measure applicable to the style in other countries.

The earlier buildings of Christian Rome were merely a degenerate imitation of the older buildings. From the establishment, if not from the tolerance, of Christianity the ancient basilicas were employed as churches; and the earliest churches erected, were modelled on the type of the basilica. Presbyteries, chapels, and other features were gradually added, and ultimately the church assumed the form of a Latin cross; but even then the principles of the basilica form were retained. [Basilica; Church.] In the buildings of the degenerate Roman period it was usual to employ the materials as well as to imitate the forms of the older edifices and columns, and other ornamental fragments were appropriated to places which they could only be made to fit by various modifications and contrivances. Hence the classic proportions, at first little heeded, were soon entirely forgotten, and the different parts of the building were designed according to the necessities of the case, or the taste or caprice of the architect. Arches were made of all sizes and placed anywhere. Columns were arranged without regard to the orders; and the dimensions of the shafts were regulated merely by the weight they had to sustain. Mouldings and carvings assumed the most irregular and fantastic patterns.

Thus, then, we perceive, when Romanesque architecture was emerging from the chaos, references in all its parts to ancient Roman forms and principles, but the utmost licence in their application; and what the architects of the period did, was to reduce the discord into order, and to mould the whole into a consistent system. Among the distinctive characteristics of this style in its maturity may be mentioned in the first place, its general massiveness of construction and severity of character. The walls are usually of great thickness and pierced by windows of a comparatively small size and few in number. Indeed, in nothing does pointed Gothic differ more markedly from the round-arched style out of which it grew than in the enlargement and the prominency given to windows—a characteristic due to the introduction of painted glass, and the admiration felt for it by the ecclesiastics of the west and north,—the decorations of the Romanesque, essentially of Italian origin, having been chiefly mural paintings and mosaics. But besides the massiveness of construction, a leading characteristic is the predominance of horizontal lines in the general composition, which again distinguishes this style from Pointed Gothic, in which a general tendency to verticality is as decidedly apparent.

The semicircular or segmental arch is distinctive of the style. It is employed for all purposes, and occurs of all sizes in the same building. Usually it is employed in combination with the columns, the column being made the essential support of the arch—all appearance of entablature being now discarded. At first the columns themselves were mostly tapering, not cylindrical like the slender detached ones met with in the Pointed style, and the capitals bore a more or less close resemblance to those of the Corinthian order in contour and proportion. The capital itself, however, was larger in proportion to the rest of the column, thereby affording a greater surface or impost for the arches to rest upon; and also combining the appearance of security at that point with general lightness of appearance. The shaft was mostly plain, yet frequently highly ornamental, striated or carved in different ways, and sometimes twisted, either singly or with two stems twining spirally round each other. Columns furnishing examples of all these different modes occur in the cloisters of San Paolo and San Giovanni Laterano at Rome, and the capitals present quite as much variety, it seeming to have been the aim on such occasions to introduce as much diversity as possible, instead of so arranging the columns as to have two of the same kind placed together: a practice probably originating in making use of fragments taken from other buildings, and afterwards retained as conducing to variety and richness.

Although the arches were, as frequently as not, quite plain, and without archivolt mouldings of any kind, the use of archivolts was by no means uncommon; sometimes consisting of merely a single moulding enclosing a plain border around the arch, at others divided into *fasciæ*, and more or less enriched, as in the front of the cathedral of Pisa, in which building the arches describe more than a semicircle above the capitals of the columns, being prolonged downwards by a deep abacus, consisting in some places of two, in others of a single plain block resting immediately on the capital. Similar blocks or *abaci* occur in the remains of Frederick Barbarossa's palace at Gelnhausen, where small heads or masks are introduced immediately above such abaci, so as to fill up the same space there between the arches, and continue in some degree the vertical lines produced by the columns.

In some Romanesque buildings the design consists of little more than an assemblage of arches variously disposed, the apertures for windows being few and small and destitute of ornament; and they generally form either successive tiers, one above the other, like so many blank galleries, or occur at intervals in the vertical line of the edifice. In these kinds of arcades [Arcade], that which is uppermost is generally of much smaller dimensions than the one beneath, so that two of its arches occupy no wider space than one of those below it. Another practice peculiar to this style is that of carrying a range of arches beneath a gable, ascending one above the other in the same sloping direction as the sides of the roof; instances of which occur in the fronts of the Duomo at Parma, San Michele at Pavia, and in those of the cathedral at Carrara, and the church of San Zeno at Verona, in which two latter instances, however, the bases of the columns are all on the same level, and consequently the columns themselves gradually increase in height as they approach the centre. The front of the cathedral at Pisa offers a double instance of the same kind in the upper, or gable story, and in the half gables over the ends of the second one, with the difference, that in the latter the pillars support merely blocks placed beneath the inclined line of the roof. To this may be added the very prevalent custom of making an upper cornice or border of very small interlacing arches, or of mouldings producing that appearance. Interlacing arches were also very common in the decorative arcades.

Among the other more prominent characteristics of this style, which are all that we can here touch upon, it should be noticed, that whether forming actual porticos and galleries, or closed up and applied merely as decoration, the arcades were generally small in proportion to the building itself, and instead of occupying the entire width of the front, or other elevation, were mostly inserted into distinct compartments of it, slightly recessed within the general face of the wall, so that the plain spaces between them assumed the appearance of buttresses, or, when narrow, of plain pilasters continued up to the cornice of the gable or roof, and cutting through whatever string-courses, or other horizontal mouldings (if there were any), divided the different stories or stages of the edifice. Such buttress-like surfaces—for buttresses they cannot properly be termed—were occasionally more or less enriched; sometimes so much so, as to produce vertical lines of ornament continued the entire height of the building, as in the front of San Michele at Pavia. When, as was frequently done, these surfaces were made wider at the angles of the front than elsewhere, they gave an expression of repose and of great solidity to it, serving as it were as a frame to the architectural decoration.

Pinnacles are of rare occurrence, and when introduced have the look of being set on the part they rise above, being separated from it by horizontal mouldings; besides which they are generally low, and somewhat resemble pedestals. Pinnacles of this description may be found surmounting pilaster-breaks, and cutting through either an horizontal cornice or the sloping cornices of a gable, as in the front of the cathedral at Monza.

Windows, as we have said, were for the most part sparingly introduced, and of small dimensions, so that they rarely contributed much towards embellishment; circular or wheel windows are, however, not unfrequently introduced in gables, and often with considerable effect. Doorways were generally made very important features, the chief ornament being lavished upon them. The aperture itself indeed was generally plain, and also square-headed, but it was enclosed in a recess formed by a series of arches one within another and resting upon columns; and so deep was this outer casing as to be frequently very nearly as wide as the actual doorway. Sometimes the tympanum was filled with sculpture, and the arches and capitals were very richly carved.

Vaulting is another important characteristic of the style. At first the ordinary Roman semi-cylindrical or waggon vaulting prevailed; but the awkward appearance of continuous vaulting supported by disconnected columns seems to have soon arrested attention, and the Roman quadripartite vaulting was introduced. This was succeeded by sexpartite, which met most of the immediate requirements of the case, but led to other innovations which in turn introduced new changes. Indeed, as Mr. Whewell, Mr. Scott, and other distinguished authorities have suggested, and as appears highly probable, it may have been the unceasing efforts of the builders to improve the system of vaulting which led to the use of the pointed arch, and ultimately to the adoption of the pointed style.

There are other points on which we might dwell, as the general employment of the apsidal termination, and the use of the triforium and the clerestory, but for these features it must suffice to refer to the articles Apsis, Clerestory, and Triforium; and again for the illustrations of details omitted here to Norman Architecture. We may, however, just add a word or two on *Towers*, a new and important feature in this style of architecture. In Italy, towers only occur as detached buildings [Campaniles], but in the Romanesque churches of Germany, France, and England, they are an essential and very characteristic portion. As the rule they are square in plan; massive in structure; pierced with a few narrow, round-arched windows, which are often coupled and enclosed with a larger arch; the surface is often ornamented with arcades; and they are surmounted occasionally with a low pyramidal spire. [Norman Architecture; Spire.] Occasionally round, and more rarely octagonal, towers are met with. In some towers circular windows are seen.

Cupolas occur in many Italian and some French churches of this date; but these may be regarded as evidence of a more or less direct Byzantine influence.

ROMANS, EPISTLE TO THE. The Epistle to the Romans has been almost universally admitted to be the work of St. Paul. The only sects which have disputed its genuineness are the Ebionites, the Encratites, and the Cerinthians, and these purely on doctrinal grounds, inasmuch as the doctrines of this Epistle were adverse to their own opinions. (Stuart's 'Commen. on the Epis.,' p. 42.) Some modern commentators, however, have supposed that the Epistle properly ends with the fifteenth chapter, a supposition which may seem plausible from the want of connection between the last chapter and the rest of the Epistle. But this want of connection may be accounted for easily enough, without any such hypothesis. (Stuart, 'Introd.,' p. 49.)

The verses 25-27 inclusive of this last chapter are in some manuscripts, as in the Codex Alexandrinus, made to follow ver. 23 of cap. xiv., and Griesbach and others give them this arrangement. But a doxology of so sublime a character as is contained in these verses does not seem a fit conclusion for a discussion about eating meats or abstaining from them, and accordingly Hug and others agree with the received text in placing them at the close of the Epistle. Some few manuscripts omit them altogether. The words *I, Tertius*, &c., xvi. 22, imply that this chapter formed the end of the Epistle, and that the Epistle is *one*. There are, however, indications in the last chapter that the Epistle received several unimportant additions or insertions after it was in the main completed, according as any afterthoughts occurred to the writer, before it was finally despatched.

With respect to the date of the Epistle, various years have been assigned to it, from A.D. 55 to A.D. 58. According to the most probable opinion, it was written towards the end of 57 or in the beginning of 58, when St. Paul was at Corinth, and on the point of setting out to Jerusalem with the "contribution made by them of Macedonia and Achaia for the poor saints which were at Jerusalem" and in Judæa (xv. 25, 26), and before he had ever visited Rome.

The Epistle was dictated in Greek by the Apostle to Tertius, his amanuensis (xvi. 22), and conveyed to the church at Rome by Phœbe (xvi. 1), a servant or deaconess of the church at Cenchreæ, a place not far from Corinth. Another proof of the Epistle having been written from Corinth is given in xvi. 23, where St. Paul sends salutations from Gaius, his host, and Erastus, the chamberlain of the city of Corinth. (Comp. 2 Timoth, iv. 20; and 1 Cor., i. 14.) The position of this Epistle in the New Testament does not depend upon its date, for it is the seventh in order of time according to most authorities, and is placed first, either from being the "longest and most comprehensive" of the Epistles of St. Paul, or from the importance of the church to which it was addressed. (Horne's 'Introduct.,' vol. iv.) With respect to the origin of this church, we have no certain information in the Scriptures. They do not tell us when or by whom it was founded. The opinion that it was founded by St. Peter does not appear to rest on any satisfactory evidence: the chief authorities for it are, Irenæus ('Adv. Hær.,' iii. 1) and Eusebius ('Chron. an. 2 Claud.'); but if he had indeed preached the Gospel at Rome, such a circumstance would probably have been noticed in the Acts of the Apostles, nor is it likely that St. Paul would have made no allusion to it in this Epistle. Perhaps the most reasonable opinion on the subject is, that the Gospel was first preached at Rome by "the strangers from that city, the Jews and proselytes," who were converted by Peter's preaching at Jerusalem on the day of Pentecost (Acts, ii. 10); so that, like many other churches, that at Rome was at first composed of Jews, and gradually increased by the admixture of Gentiles, till the whole Christian community there became so large and important, "that their faith was spoken of through the world." The fact of this combination and co-existence of Jews and Gentiles as parts of one Christian church sufficiently explains to a careful reader the occasion and object of the Epistle. Prejudices and pretensions on one side would be met with disdain or opposition on the other. (Cap. ii. and xi.) The Jews were attached to the Mosaic institutes, and the Levitical rites and distinctions between clean and unclean. They were impatient of subordination to or equality with the Gentiles, and wished to impose upon them a conformity to many points of the Mosaic ritual, especially that of circumcision, before they were admitted to a participation in the privileges of the Gospel. The Gentiles, on the other hand, disregarded (perhaps too contemptuously) the prejudices of the Jews, and were of course offended at their pretensions to superiority, for which their fallen position afforded in the eyes of the Gentiles no justification. They might not reflect with fairness on what the Jews conceived themselves to have lost by the publication of the Gospel. Such a position of parties, and such a state of feeling between them, would naturally give rise to the divisions and offences which occasioned some of the admonitions and cautions contained in the hortatory portion of the Epistle, and the existence of it can scarcely fail to be observed by a careful reader.

For examples of undesigned coincidence between this Epistle and the Acts of the Apostles, the reader is referred to Paley. The writers and commentators upon this Epistle, both English and foreign, have been exceedingly numerous.

RONDEAU (Fr.), or RONDO (It.), a kind of air consisting of two or more strains, in which, after finishing the second strain, the first is repeated, and again after the third, &c., always returning to and concluding with the first. (Rousseau.)

ROOD, the quarter of an acre. [Acre.]

ROOD-LOFT. In Roman Catholic churches a large crucifix usually occupies a conspicuous position at the entrance to the chancel. Prior to the Reformation the same custom was, of course, observed in English churches. The crucifix, here called a *Rood*, was placed on a beam—called the *Rood-Beam*—fixed across the chancel arch, or on the screen which divided the nave from the chancel; but more commonly in large churches the Rood was placed on a gallery called the *Rood-Loft*. The rood was of large size, painted in natural colours, sometimes ornamented in front with the emblems of the evangelists; and had figures of the Virgin and St. John standing one on each side of the foot of the cross—the figures being all turned towards the nave. The screen which supported the gallery was of wood or stone, often richly carved or panelled. A flight of stone steps in the wall of the nave usually led to the rood-loft; but in some instances the stairs were carried up an external turret. Roods are of great antiquity. A cross surmounting a chancel screen in the church of Santa Sophia, Constantinople, is mentioned by a writer of the 6th century; but there is no evidence of such a cross having a figure of Christ upon it before the 8th century. In England roods were introduced as early as the 11th century; but rood-lofts seem to have been first erected in English churches in the 14th century. The galleries as well as the roods were in most instances destroyed by authority in the reign of Edward VI., but more or less perfect examples remain in various country churches, among others at Banwell, Long-Sutton, Minehead and other churches in Somersetshire; Newark, Nottinghamshire; Great Handborough, Great Rollwright, and Charlton, Oxfordshire; Dartmouth and elsewhere in Devonshire; and Worm-Leighton, &c., Warwickshire. In some churches a small turret was erected over the chancel arch, and consequently over the rood, in which was hung the sanctus bell [Bell-Cote], and this was often called the *Rood-Tower*. The chancel-arch in like manner, from the rood being placed beneath it, was sometimes termed the *Rood-Arch*. On the continent the gallery-cross, in French *Croix de jubé*, had gradually fallen into disuse sometime before the present century, and old examples are now very rare. One of the most perfect is in the great church of Louvain. In Germany, France, and the Netherlands, the rood was often suspended from the chancel arch by three ornamental chains, of which fragments still remain in several churches.

ROOF, the covering of a house or other building. The name, in its most extended sense, embraces the external covering itself, and the framework by which it is supported; but, as a term in carpentry, it is limited to the carcass-roof or framing.

The importance of this part of a building can hardly be overrated, since on its right construction depends not only the comfort of those for whose shelter it is designed, but also the safety and durability of the edifice itself. For the former of these purposes it is desirable that a roof should exclude extremes of heat and cold, and be impervious to rain or snow. For the latter, the exclusion of water is equally necessary; and it is essential that the framework be so disposed as to throw the least possible strain on the walls. By a judicious arrangement in this particular, a roof may not only be prevented from pressing on the walls in an injurious manner, but may be made to contribute greatly to the stability of the whole structure. In order to the due combination of the requisite qualities, an intimate acquaintance with the principles of mechanical philosophy is indispensable; and a correct knowledge of the strength of different materials, when exposed to various kinds of strain, is necessary to the economical adjustment of the dimensions of the several parts of a roof. A roof of large span forms, indeed, one of the most interesting applications of the science of carpentry, theoretical or constructive.

In order to cover in a building in which the space to be spanned is greater than can be covered by single blocks of stone extending from one point of support to another, it is necessary either to have recourse to the principle of the arch, as in vaults and domes of stone or brick, or to form a framework of timber to support the covering. The former plan is objectionable in the case of ordinary buildings from its expense and weight, and from the great solidity required in the walls, where they have to be used as the abutments of an arch. The principles on which such coverings of masonry are formed are explained under Arch and Dome; and in this article the more usual kind of roof, that sustained by a wooden framing, will be described. Such structures occasionally partake of the character of an arch or dome, but more usually consist of flat planes variously disposed. Roofs formed of one level plane, which are extensively used in eastern countries, are not adapted for buildings in which a large space has to be spanned over, nor to resist the penetration of water, and are therefore unsuitable for climates in which rain and snow are common. A simple inclined plane is well adapted to resist injury from weather; but, as it is scarcely more favourable to an economical disposition of the timbers than a flat roof, it is only suited for small buildings, and is seldom used except as a lean-to. Another objection to its use on a large scale is the disproportionate height it requires on one side of the building. The best figure for a simple roof is that formed of two inclined planes, rising from the two opposite walls that approach nearest to each other and meeting over the centre of the edifice, so as to form a ridge. By this form, supposing the same slope to be maintained, one-half of the height of the single inclined plane is avoided; and the length of the timbers being diminished one-half, their scantling may be considerably reduced. *Fig.* 1 represents a plan with side and end views of such a roof, which is called a *common* or *gable-ended roof*. Frequently four inclined planes are used, disposed as shown in *fig.* 2, representing a *hipped roof*, which takes its name from the hips, or inclined ridges formed by the meeting of the sides and ends. Where a hipped roof covers a perfectly square building, the faces all meet in a point, and form a pyramid; but when, as in the diagram, the plan of the roof is oblong, the planes rising from the nearest opposite walls meet in a ridge. Sometimes the inclined faces are not continued upwards till they meet, but the roof is completed by a horizontal plane. Such a roof is called a *truncated*, *terrace*, or *cut roof*, and may have two, three, or four inclined faces. *Fig.* 3 represents a truncated roof hipped at one end, and terminating at the other in a vertical wall, like the gable-ended roof.

Fig. 1.

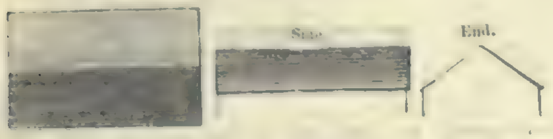


Fig. 2.

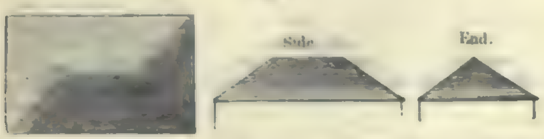
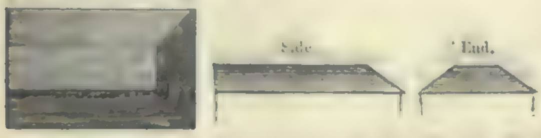
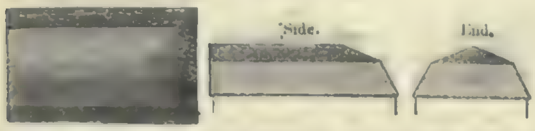


Fig. 3.



This arrangement is useful for diminishing the height of a roof, the level platform being covered with lead to compensate for the want of slope. It should be observed, however, that even this part is not perfectly level, the centre being slightly elevated to throw off water. A similar saving of height is frequently obtained by means of a roof in which each sloping face consists of two planes of different degrees of inclination. This form, which is denominated a *curb roof* (or, from its inventor, a *Mansarde roof*), is very common in London, because it affords more space for the formation of bedrooms in the roof than the simpler forms. A curbed roof may be hipped or not, according to circumstances. *Fig.* 4 represents it hipped at one end only, as the last figure, showing, like the previous diagrams, the plan, and side and end elevations.

Fig. 4.



Such are the principal forms of roof used in covering simple rectangular buildings, but they require many modifications to suit irregularities of shape or combinations of rectangular forms. Thus, in *figs.* 5 and 6, which represent the junction of different roofs or portions of roofing at right angles with each other, the lines *a a a* indicate *valleys*, or the junction of two planes in such a manner as to form hollows the reverse of hips. When two faces of a roof join so as to form an angle similar to a valley, but in a horizontal instead of an inclined position, the term *gutter* is applied instead of valley.

Fig. 5.

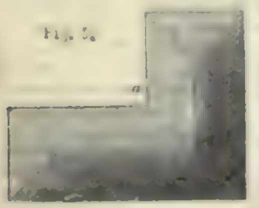
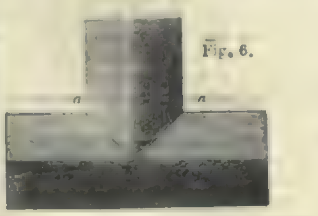


Fig. 6.



A further distinction, which it may be well to mention before entering upon the details of construction, is that between roofs with dripping eaves, and those in which the water is collected in gutters. In the former case the roof projects several inches, or even feet, beyond the walls, and the water running from the roof either drops at once on the ground, or is collected in troughs fixed under the margin of the eaves, and conducted by them to descending pipes. This arrangement has a clumsy appearance, and is perhaps unnecessary where a sufficient projection is given to the eaves, though it is essential to the dryness of the walls when they are of the diminutive size often adopted by modern builders. In gutter roofs the timbers do not extend to the outside of the walls, which are carried up as parapets, of a reduced thickness, to such a height as to conceal the roof either wholly or partially. The gutters, which are troughs of wood covered with lead or other metal, are laid at the bottom of the slopes, just within the parapets, and have a gentle inclination (usually about an inch in ten feet), to cause water to run freely towards the pipes. In extensive roofs it is well to use two or more falls instead of one, that the elevated end of the gutter may cover as little of the roof as need be. Similar troughs are often used in the valleys. Gutters are generally made wide enough for a man to walk along them, and should be sufficiently capacious to avoid all risk of overflowing during a sudden heavy fall of rain.

The degree of slope given to the inclined faces of a roof varies according to the covering material employed, as well as to the climate. The ancient Grecian temples had very low, or pediment roofs, varying from about 12° to about 16°, the height being from one-ninth to one-seventh of the span. In Roman buildings the inclination is somewhat greater, being usually 23° or 24°, or from one-fifth to two-ninths of the span. The general introduction of the pointed style of architecture led to the use of very high-pitched roofs, a very common proportion being that in which the length of the rafters is the same as the span, so that they formed an equilateral triangle. In comparatively modern domestic architecture in this country, it has been considered desirable for the length of the rafters to be three-fourths that of the span, and an angle of 45° is still considered by some to be the best pitch when plain tiles are used. As builders can, in the present day, obtain excellent covering materials, the pitch may be made of any required degree, down to the low Grecian pediment, and it therefore depends on the style of architecture and the taste of the builder; the most common height being from one-fourth to one-third of the span. High roofs discharge rain the most rapidly, and do not retain snow so much as those of low pitch; but where they have gutters they are liable to become choked by snow sliding into them, and to overflow from water running into them faster than the pipes can convey it away. Steep roofs may be covered with small slates, and are less likely to be stripped by violent winds. Low roofs, in consequence of their superior lightness, are less expensive, the timbers not only being shorter, but of proportionately smaller scantling, and they press less injuriously on the walls. The following table, extracted from Tredgold's 'Elementary Principles of Carpentry,' shows the proper angle for roofs covered with the materials specified in the first column, the last column indicating the comparative weight of each kind of covering:—

Covering.	Inclination to the horizon.	Height of roof in parts of the span.	Weight upon a square of roofing.*
Copper or lead	3° 50	$\frac{1}{48}$	copper 100 lead 700
Slates, large	22°	[illegible]	1120
„ ordinary	26° 33′	[illegible]	900 to 500
Stone slate	29° 41′	[illegible]	2380
Plain tiles	29° 41′	[illegible]	1780
Pan-tiles	24°	[illegible]	650
Thatch of straw, reeds, or heath	45°	$\frac{1}{2}$	

In describing the timber-work of an ordinary roof, each of the planes of which it is composed may be considered to be bounded by a frame, the parts of which have the general name of bordering pieces. Those which join the wall are the *wall-plates ;* that at the meeting of two faces, parallel to the wall-plates, is the *ridge-piece ;* and the inclined bars extending from the wall-plates to the ridge-piece are *rafters*, those which form the salient angles in hipped roofs being distinguished as *hip-rafters*. The support necessary for the external covering is given by a series of rafters or inclined bars, extending from the wall-plate to the ridge-piece, and placed parallel with each other at equal distances. In a hipped roof, the rafters near the ends, being parallel with the others, are necessarily diminished in length, extending from the wall-plate to the hip-rafter instead of the ridge-piece. All such pieces, being shorter than the length between the wall-plate and the ridge-piece, are called *jack rafters*.

It is not usual to vary the scantling, or transverse dimensions of rafters, in any considerable degree, on account of their various lengths; nearly the same scantling being used in all buildings, and the required strength being obtained by introducing intermediate supports between the wall plates and ridge-piece where the size of the roof renders such necessary. This additional support is supplied by horizontal rectangular bars called *purlins*, placed under the rafters in such a manner as to divide their length into two or more equal parts, the ends of the purlins being fixed to the sides of the bordering frame. Like the rafters, the purlins are not much varied in thickness according to the strain upon them, but they are in turn supported by a series of bars placed equidistant from each other, and parallel with the rafters. but with their upper face in the same plane as the lower face of the purlins. These are called *principal rafters*, or, for brevity, *principals*, to distinguish them from the first described, or *common rafters*. Where it is desirable to save room by reducing the thickness of a roof, the purlins may, as shown in *fig.* 15, be notched into the principals and common rafters, but this practice is not to be recommended, as it weakens the timbers. Where principals are used, their lower ends are morticed into the ends of a *tie-beam*, which stretches across the building, and rests upon the wall-plates. This beam keeps the lower extremities of the principals from separating, and discharges the weight of the roof on the walls in a vertical direction, relieving them entirely from the lateral thrust of the rafters. The triangular frame formed by the two principals and a tie-beam, with any bars it may comprise for additional strength, is called a *truss*, and such frames being placed at regular intervals, the timber work between any two of them is called a *bay of roofing*. The lower extremities of the common rafters, being elevated by this arrangement above the wall-plates, are supported by *pole-plates*, or pieces of timber parallel to the wall-plates, resting on the ends of the tie-beams. The supporting frame-work altogether is called a *carcass-roof*.

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* A square of roofing contains 100 square feet.

Fig. 7, which represents a small carcass-roof supported by four trusses, and having one purlin only between the wall-plate and ridge-piece, may assist the reader in comprehending the arrangement of the parts enumerated; and their names will be found more distinctly by referring to the representation of a more complicated truss at *fig.* 11.

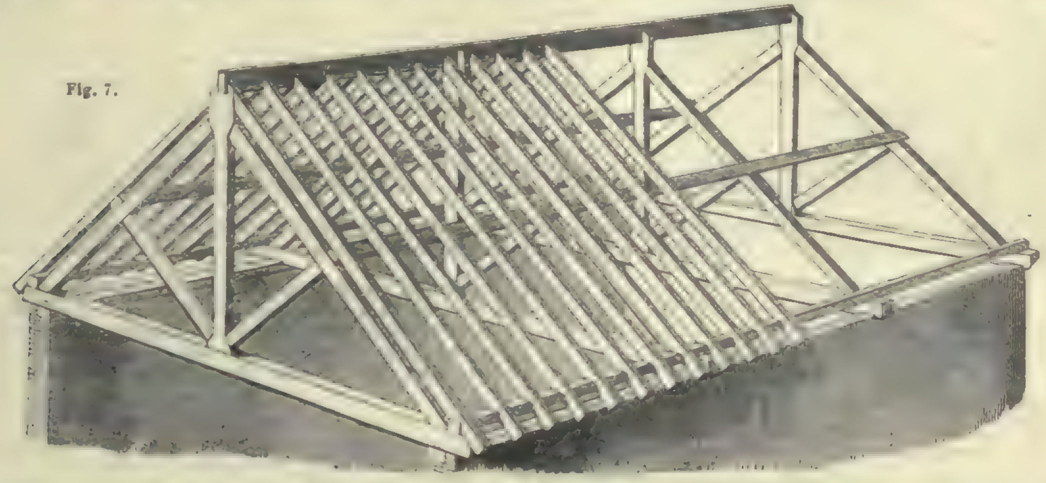


Fig. 7.

In *fig.* 7, the common rafters are represented on one half of the roof only, that the trusses may be more distinctly seen; and the end walls are omitted for the same reason.

The proper construction of the trusses of a roof, with reference to the size of the building, and the weight of the covering, is a matter requiring much scientific knowledge. For the want of this it is not unusual to encumber trusses with much more timber than is necessary or useful: and the disadvantage of this is not confined to the increased weight and cost of the roof, as superabundant timbers frequently occasion injurious strains, and the increased number of joints adds to the risk of derangement by the shrinking and warping common to all timber constructions. The general principles to be acted upon may be illustrated by a few diagrams; but in the limited space devoted to this article no attempt can be made to describe all the modifications required by the ever-varying forms of buildings; in the design of which it is too common, instead of assigning its due importance to the roof, to treat it as an unsightly feature, to be concealed as much as possible from view.

In a roof formed as shown in *fig.* 8, consisting simply of two inclined planes abutting on the walls, it is evident that the weight of the rafters *a b* and *b c*, as well as that of the covering sustained by them, will have a tendency to thrust out the walls. This tendency ordinary walls have not the strength to resist, and therefore it becomes necessary to add the beam *a c* (*fig.* 9), which by receiving the outward thrust of the rafters, relieves the walls of lateral strain. If the tension of the tie-beam *a c* be sufficient to resist the extending force of the rafters without sensible elongation, the only effect that such a roof can have upon the walls is a vertical pressure on each, equal to half its weight; and it cannot fall without the tie-beam, which acts the part of a cord or chain, being pulled asunder, or the rafters being crushed. If the materials were perfectly rigid, no additional parts would be required; but as they are not so in practice, it becomes necessary, when the timbers are of considerable length, to provide means for counteracting their tendency to sinking, or *sagging*. By adding a bar shaped like *b d* (*fig.* 10), the centre of the tie-beam may be suspended from the crown of the roof. This piece is called a *king-post*, but the name is perhaps not a good one, as, though it appears like a post to support the ridge or crown of the roof, it is in reality a *tie*, supported by it, and sustaining, instead of resting upon, the centre of the tie-beam. By cutting the king-post out of a piece of wood of larger scantling than the shank of the post itself, projections of the shape indicated in the cut may be formed at its ends. These are called *joggles*, and those at the upper end form a wedge between the heads of the rafters, like the keystone of an arch. It is evident that a weight pressing on the projecting joggles at the base of the king-post will be by it transmitted to the crown of the roof. These therefore form fixed points, from which support may be obtained, by means of *struts* or *braces*, *e* and *f*, for the centre of each rafter. Where purlins are added, they rest on those points of the principal rafters that are thus supported by struts, as may be seen by reference to *fig.* 7. It may be observed that this truss consists of two pieces (the tie-beam and king-post) in a state of tension, and four (the two rafters and the two struts) in a state of compression; and that in every well-contrived truss, however the number of its component parts may be increased, every bar is in one or other of these states. Those parts which are in a state of tension, acting merely as cords to bind the truss together, may be and sometimes are formed of slender rods of wrought-iron; but the others, needing stiffness as well as cohesion, require bars of considerable substance, and are therefore mostly formed of wood or cast-iron. Sometimes the king-post is dispensed with, and its office performed by two similar posts, called *queen-posts*, at equal distances from the centre of the truss. In order to keep these in their right position, a short horizontal beam, called a *collar-beam*, is inserted between their upper extremities, and another, termed a *straining sill*, between their lower ends. This arrangement is explained by *fig.* 11, which also shows the position of other parts of a truss. One side is represented as a gutter-roof, and the other with eaves.

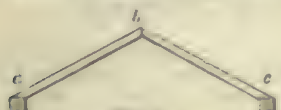


Fig. 8.

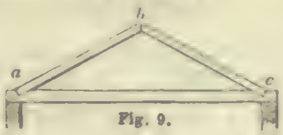


Fig. 9.

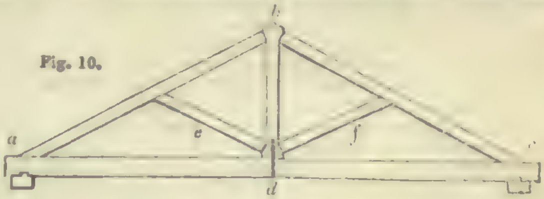
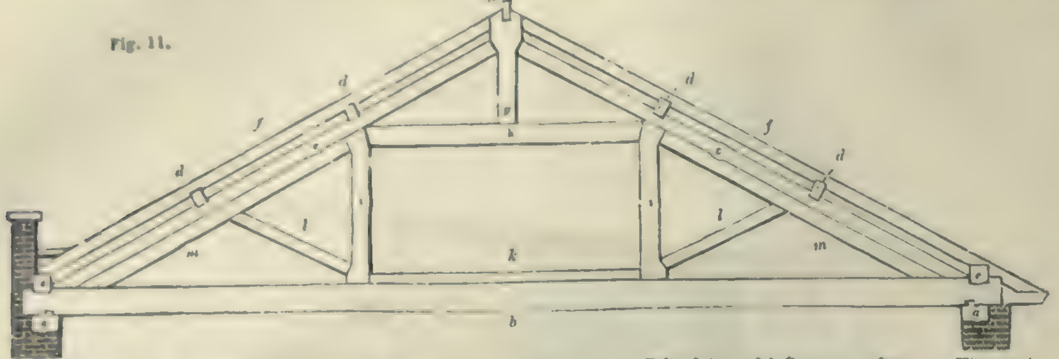


Fig. 10.

The *auxiliary* or *cushion rafters*, *m*, *m*, are pieces occasionally added, in large roofs, to strengthen the principals; and they, with the collar-beam, &c., form a complete truss within them. The trusses of truncated roofs are formed in this manner, the collar beam forming, as it were, the keystone of the arch, and being surmounted by a *camber-beam*, the upper edge of which is formed into two slightly inclined planes, to give the necessary slope to the lead covering. In such a roof, pieces of wood resembling ridge-pieces are inserted at the angles formed by the meeting of the rafters with the horizontal bars that support the flat.

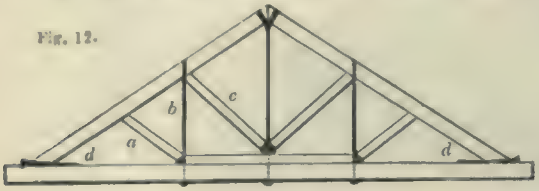
Fig. 12, is a representation of a very simple truss, from Nicholson's 'Carpenter and Joiner's Companion,' which illustrates the use of slender king-posts and queen-posts of wrought iron, and shows how the stress of every part of the roof may be brought to bear on the ridge. The lower ends of the struts rest in stirrups attached to the vertical rods and the weight bearing on the strut *a* is imparted, through *b* and *c*, to the king-post. The tie-beam is suspended by bolts from each of the vertical rods, and the ends of the rafters are secured to the tie-beam by iron straps passing round them, and bolted to the beam at *d*, *d*. Trusses on the same principle may be made of timber only.

Fig. 11.



a a, Wall-plates; *b*, Tie-beam; *c c*, Principal rafters; *d d d d*, Purlins; *e e*, Pole-plates; *f f*, Common rafters; *g*, King-post; *h*, Collar-beam; *i i*, Queen-posts; *k*, Straining-sill; *l l*, Struts or braces; *m m*, Auxiliary rafters; *n*, Ridge-piece.

Fig. 12.



In curb roofs the upper rows of rafters are called *curb-rafters*, and the horizontal bars that receive the upper ends of the lower rafters, and the feet of the curb-rafters, are known as *curb-plates*. The proper position of equilibrium for the rafters of a curb-roof may be ascertained by very simple means, within the reach of persons not possessed of sufficient mathematical knowledge for determining it by calculation. If the rafters are to be equally loaded, as in a roof entirely covered with one material, this position will be exactly the reverse of that which they would take by gravity, were they suspended in a chain or festoon, the joints being flexible. If they are framed together in this position of equilibrium, they will balance each other like the stones of an arch; and the tie-beams, posts, and braces will have no other office to perform than that of resisting such irregular strains as might tend to alter their arrangement. The rafters thus suspended would fall into the position *a b c d e*, *fig.* 13, a line drawn through the angles being a catenarian curve; and *a′ b′ c′ d′ e′*, in the same figure, represents the corresponding position in which they should be placed in an equally loaded roof. If the rafters *b′ c′* and *c′ d′* are to bear a greater weight than *a′ b′* and *d′ e′*, they will, if proportionately loaded when suspended in a curve, fall in such a way as to increase the angles *a b c* and *c d e*, and diminish *b c d*, thereby indicating their proper position in the roof. When the roof is to be loaded unequally, and more on one side of the ridge than the other, as it would be if *b′ c′* were to be covered with lead, and the other planes with slates, a corresponding weight added to the centre of gravity of *b c* will cause the bars to arrange themselves as *a b c d e*, *fig.* 14, the angles of which, being transferred to the roof, give the position of equilibrium *a′ b′ c′ d′ e′*. This practical method of finding the proper angles of a curb-roof may be applied under all circumstances, the dimensions of the experimental bars being proportionate to those of the rafters, and their centres of gravity being loaded according to the pressure to be sustained by each plane of the roof. The great advantage of curb-roofs consists in the space they afford for chambers in the roof, such chambers being lighted by dormer windows in the lower inclined faces. When the trusses of the roof form partitions between the bed-rooms, their posts and braces are so arranged as to leave one or more doorways for communication between them.

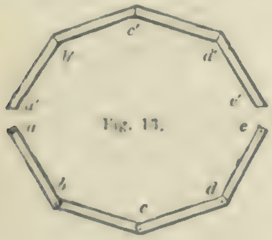


Fig. 13.

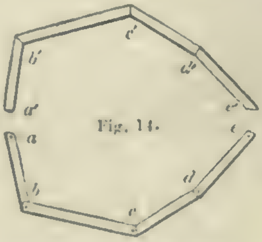


Fig. 14.

In roofs of very large span it is often desirable, in order to avoid running up to a great height, to form two or more ridges. When intermediate support can be obtained from partition walls, such constructions may be regarded as combinations of two or more distinct roofs placed side by side. *Fig.* 15 is an example of a roof of large span without any intermediate support, and having a large available space between the tie and collar beams. It represents the form of the trusses, which were placed fifteen feet apart, of a roof of eighty feet span, erected over Drury-Lane Theatre in 1793.

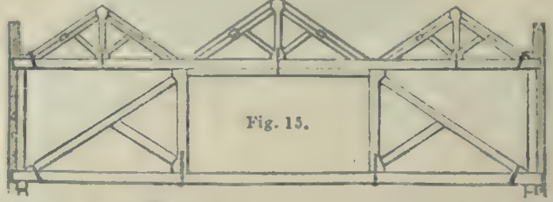
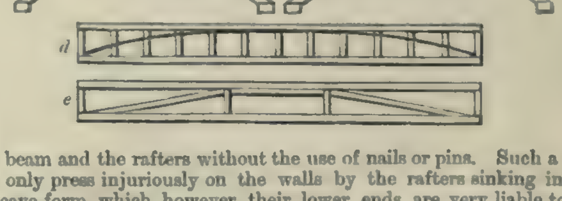


Fig. 15.

It is sometimes necessary, in order to obtain additional height inside a building, to raise the tie-beam above the level of the top of the walls. In small spans this may be done by the simple arrangement called the *carpenter's boast* (A, *fig.* 16), in which a firm union is effected between the beam and the rafters without the use of nails or pins. Such a roof can only press injuriously on the walls by the rafters sinking into a concave form, which however their lower ends are very liable to do. In such a case additional strength may be obtained by inserting a longitudinal truss, as in B, *fig.* 16, where *c* represents the end of the truss, which should be firmly built into the gables: *d* and *e* are side views of two longitudinal trusses suitable for such a situation, the first being stiffened by an arch of iron notched into the short vertical pieces, and the second formed of timber only. Similar trusses are occasionally introduced under the purlins. Roofs without ties may be greatly strengthened by the use of parabolic curves of iron, notched into the rafters of each inclined face, and abutting on the wall-plates, which in such a case are firmly bolted together. The timbers of such a roof may be framed together in planes, each having a distinct ridge-piece, and the ridges being screwed or otherwise firmly connected together. The curves may be cast in short segments, as they are compressed when in use, it being merely necessary to provide that the joints should always abut on a rafter. Tredgold, in his 'Elementary Principles of Carpentry,' recommends the use of similar curves, of either wood or iron, in the trusses of an ordinary roof, by which the derangement often arising from the shrinking of the king-posts and queen posts may be avoided. In this case the curves take the place of the principal rafters, and, if made of wood, may be constructed of

Fig. 16.



short straight pieces, arranged as shown in *fig.* 17, and held together by bolts or wooden keys. When curved timber can be obtained it is to be preferred, as it reduces the number of joints. For small roofs timbers may be bent into the required form, as it is found that a piece of wood the thickness of which does not exceed $\frac{1}{120}$th part of its length, may be bent into a curve rising one-eighth of its span without impairing its elasticity. Two such pieces may be laid together, and bent by twisting a rope attached to their ends, as is done in tightening the frame of a bow or pit saw; and, being bolted together while curved, they will spring back but little when the rope is relaxed. Another mode of forming such a rib is to take a piece of wood whose thickness is about one-sixtieth of its length, and cut along the middle with a thin saw from each end, leaving about eight feet in the centre solid. The beam may then be bent, and bolted or pinned together as before described. In either case the rib should be bent about one-fourth more than it is intended to remain, to allow for springing back. A parabolic curve is the form most recommended; but a circular arc, rising half the height of the roof, will answer the purpose. *Fig.* 18 represents the truss of a truncated roof strengthened by a curved rib, the suspended pieces being, when the rib is formed in the manner first described, placed at each joint, and each consisting of two pieces, one on each side of the rib, notched to it and the beam, and fastened by bolts and straps.

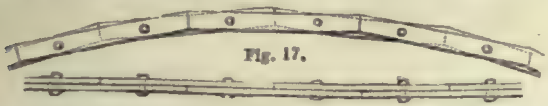


Fig. 17.

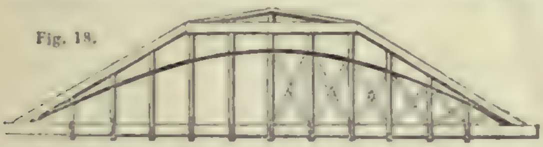


Fig. 18.

One of the advantages of this mode of construction is that the tie-beams may be suspended from any number of points, which is important in large spans, where the beams have to be formed of several pieces scarfed together. [SCARFING.] Diagonal braces, though unnecessary with parabolic curves, may be added to meet accidental strains, as shown by the dotted lines in the cut. This principle of construction, with an arc composed of several pieces of timber, was followed in one of the largest roofs ever built—that erected in 1791 over a riding-house at Moscow. The span of this roof, which has been said to be the most extensive wooden roof in the world, is stated by Tredgold at 235 feet, the slope being about 19°, and the external dimensions of the building 1920 by 310 feet. He states that it had sunk so much that it was proposed to add a second curve for additional strength.

A simple and economical roof, invented by Mr. A. H. Holdsworth, and rewarded by the Society of Arts in 1820, is supported by curved ribs of timber applied in a different manner. A detailed description is given in the 38th volume of the Society's 'Transactions;' but *fig.* 19 will sufficiently explain the principle of its construction: *a* is a beam serving as a tie-beam, and also to support the upper floor of the building; *b b* are curved ribs, formed in a similar manner to those just described, the lower ends of which are firmly secured to the tie-beam *a*. The principal rafters rest on these ribs, and their lower ends bear upon short timbers resting on the walls, these pieces being fastened by strong iron straps to the curved ribs, to counteract the outward thrust of the rafters. By this arrangement the whole of the interior of the roof, which is usually encumbered with king-posts, queen-posts, braces, &c., is rendered available for useful purposes, in addition to which it effects a considerable saving of timber.

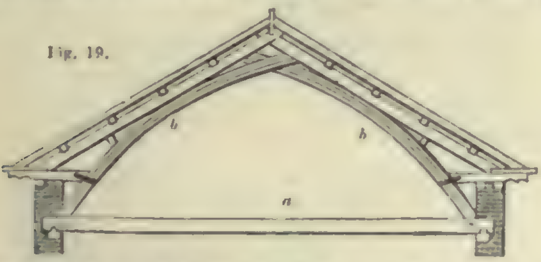


Fig. 19.

Wrought iron straps of various forms are very useful, when judiciously applied, in strengthening the joints of a roof. They should be fixed with regard to the unavoidable tendency of the timbers to shrinking, so that while they may, in some cases, counteract or lessen its effect, they may so far yield to it as to prevent a strain which should come upon a timber, being entirely thrown, by its alteration of form, upon the strap. Tie-beams are often suspended to the trussing-posts by means of straps, so arranged as to allow the beam to be keyed up to its true position in case of the roof sinking. When this is not the case, the ties are sometimes drawn up into a slightly convex or cambered form, to meet the same contingency. Height may be gained inside a building by disposing the timbers as in *fig.* 20, the want of a continuous tie-beam being compensated for by an iron strap to unite the ties to the bottom of the king-post at *a*; but it is evident that the safety of the plan must depend wholly on the straps, which alone counteract the outward thrust of the rafters.

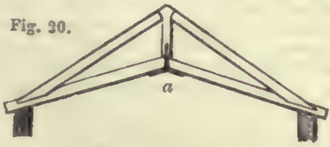


Fig. 20.

In roofing a church with a nave and side aisles, the continuity of the tie-beams may be dispensed with, intermediate support being obtained from columns. It is however necessary to guard carefully against any lateral strain to the columns.

Many of the high-pitched roofs of old Gothic churches and halls are very ingeniously contrived, but they often throw great pressure on the walls, owing to the absence or elevated position of the ties; thereby rendering very solid walls and buttresses necessary. The *Norman roof* is an ingenious but complicated contrivance for the construction of roofs of large span with small pieces of wood. *Fig.* 21 shows this arrangement, in which all the rafters abut on joggled king-posts, of which there are several, their relative position being maintained by diagonal braces. The timbers of this kind of roof are often left visible, being so carved as to have an ornamental effect. Such a roof may be made to exert very little injurious pressure on the walls.

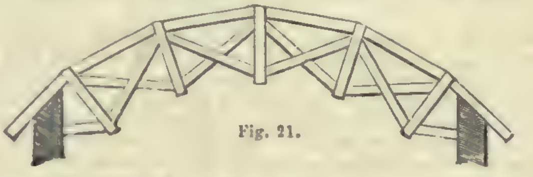


Fig. 21.

When the space covered in is of an irregular shape, it is best to arrange the inclined planes of the roof in a similar manner to those of a rectangular building, leaving a level platform in the centre, corresponding to the plan of the inclosed space. Where the space covered is circular, elliptical, or polygonal, although the construction of the roof may appear more complicated to the eye, it is, in fact, simpler and easier than that of a quadrangular building, the strain of the roof being more equally distributed. The nearer a roof approaches to a circle in plan, the stronger it will be, the parts deriving that mutual support from each other which forms the distinguishing character of the dome. Domes of wood, of great size, have been made without trussing, simply by forming the timbers into curved ribs abutting on the wall-plates, which then form a circle, and are kept in their proper positions by horizontal circles framed with them at intervals. As the ribs approach the upper part of the dome, the intervals between them diminish in width, to allow for which every second or third rib is discontinued at intervals, the ends of the ribs thus discontinued being received by the horizontal circles, which may be compared to purlins, the ribs taking the place of rafters. The wooden dome formerly existing at the Halle aux Blés, at Paris, was a remarkably bold example of this kind, being 200 feet in diameter, and having a large opening in the centre. It was built at the suggestion of M. Moulineau, and, having been destroyed by fire, has been replaced by a similar structure of iron, but of smaller dimensions.

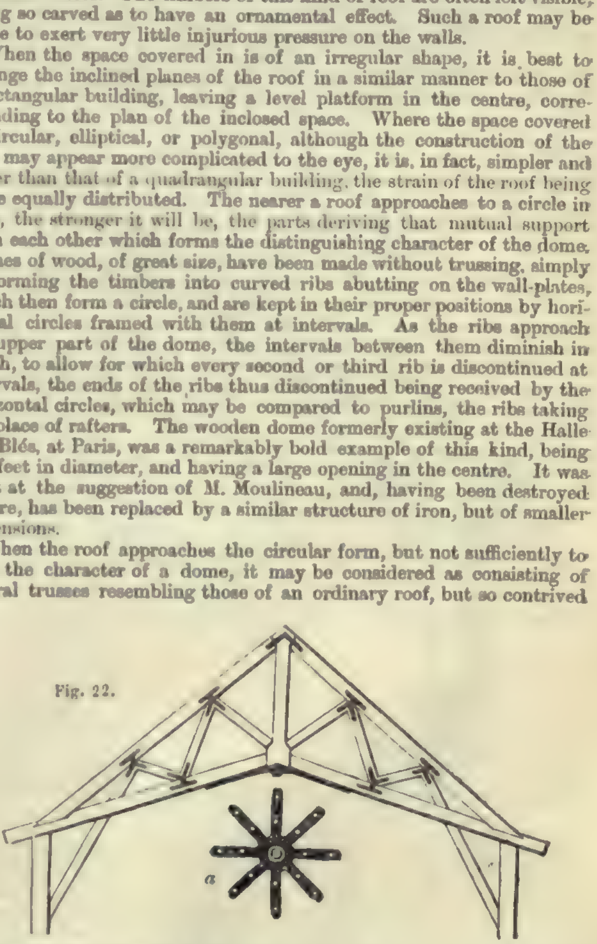


Fig. 22.

When the roof approaches the circular form, but not sufficiently to have the character of a dome, it may be considered as consisting of several trusses resembling those of an ordinary roof, but so contrived as to intersect each other in the centre; the king-post being common to all the trusses. *Fig.* 22, representing a design for a polygonal roof, from Nicholson, may illustrate this, and exemplify also some of the applications of iron straps: *a* shows the form of the strap by which the ties are secured to the king-post; the post having as many faces, and the strap as many arms, as there are trusses in the roof.

Though the number of contrivances for the construction of roofs is very great, as may be seen by reference to various works on carpentry, allusion can here be made to only one or two others. An admirably simple plan for making a very flat roof is described in the 37th volume of the 'Transactions' of the Society of Arts, in a communication from the inventor, Mr. Smart. The beams or rafters are cut, with a circular saw, as shown at *a*, *fig.* 23, while *b* represents their form when in use, a wedge being inserted between the ends of the parts that are elevated into a sloping position. These may be raised to an angle of 10° or 12°, and will bear a great weight, as they cannot be depressed without thrusting off the ends of the beam, or breaking the lower part of it by tension. This is called, by the inventor, the *bow and string rafter*, and was used by him to support a roof at the Ordnance Wharf, Westminster Bridge. Strong laths were nailed upon the rafters, and on these a platform of bricks was laid in cement, the whole being covered with tiles also bedded and pointed with cement, and twice coated with hot linseed-oil. The cost of this roof is stated to be not more than half that of lead.

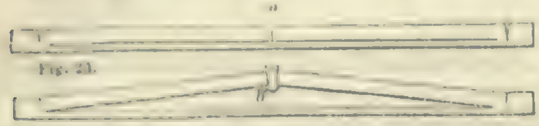


Fig. 23.

About thirty years since Colonel Emy, of the French Génie Militaire, applied, on a large scale, the system of bending thin planks into arched ribs to support the rafters of roofs of considerable span, erected over riding schools and building slips, &c.; and the system has also been applied in the construction of timber bridges for railways, with clear openings even of 133 feet. For the latter purpose the laminated timber arches have failed, on account of the entrance of moisture between the separate laminæ, and the consequent rotting of the beams; but in roofs, or in other positions where the arches are not exposed to occasional efforts of a nature to cause the laminæ to open, the beams do not rot, and there seem to be decided economical advantages in the application of Colonel Emy's system. It has been introduced in the Great Northern Railway Station in London, and in the station of the Baden Railway, at Freiburg, with great success; in both cases the spans are not less than 100 feet; the riding schools built by Colonel Emy, generally speaking, had a span of about 60 feet. A sketch of one of them is appended (*fig.* 24) and a description of the mode of putting the principals together is to be found in Emy's very valuable 'Traité de la Charpenterie.'

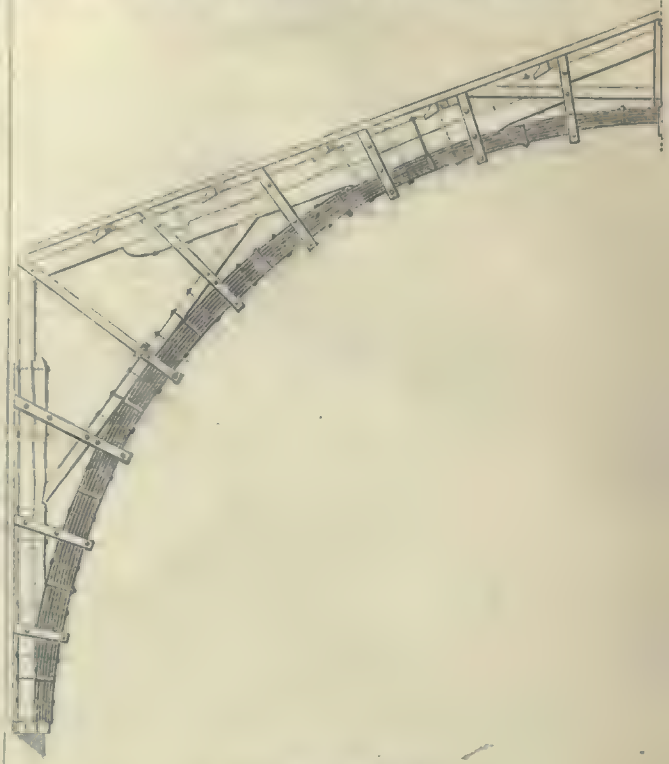


Fig. 24.—Riding School of Marac.

Colonel Ardant, also of the French Génie, has however published a work under the title of 'Études sur les Charpentes à grande portée,' in which he shows that these bent timber principals are not so advantageous, or so strong, as built beams of a polygonal form, of square timber, properly framed, and bolted together. The great objection to the use of the bent timber ribs was considered by Colonel Ardant to lie in their tendency to resume the straight line, or, in other words, the elasticity of the laminæ gave rise to a considerable force which tended to thrust out the side walls; and in fact this danger was actually found to exist at the Great Northern Railway Station, London, to so great an extent as nearly to lead to the overthrow of the whole shed. It would, however, be easy at any time to counteract the thrust of a principal of this description, and the bent timber ribs are no doubt very convenient and economical in many positions. Local considerations, therefore, ought alone to determine the selection of

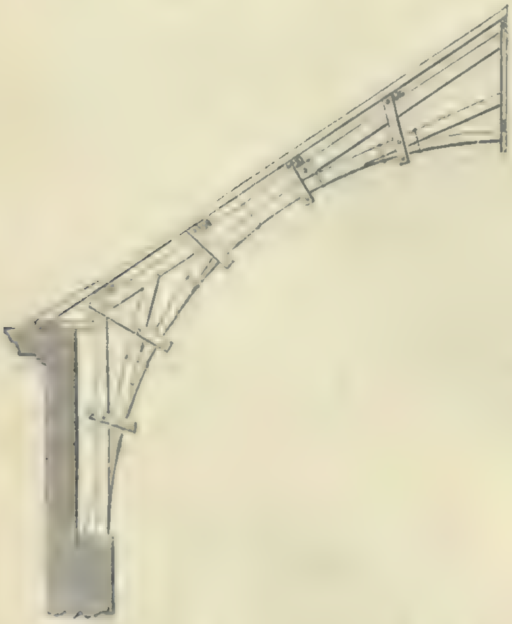


Fig. 25.—Ardant's Roof.

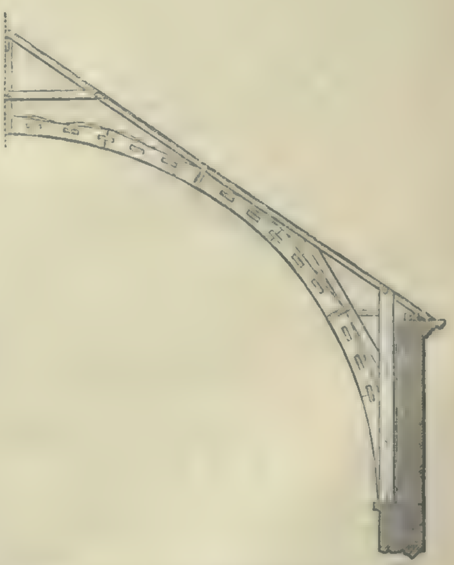


Fig. 26.—Roof of the Riding School, Metz.

either Emy, Ardant, or Philibert de l'Orme's systems of executing large timber roofs without tie-beams. In the main, they are all founded on the same principle—that of introducing a rigid beam for the purpose of supporting the principal rafter; the differences consist in the manner in which the physical properties of the wood are brought into action. In Emy's beam the elasticity of the bent planks is the great element of resistance; in Ardant and de l'Orme's principals, the wood resists mainly efforts of compression.

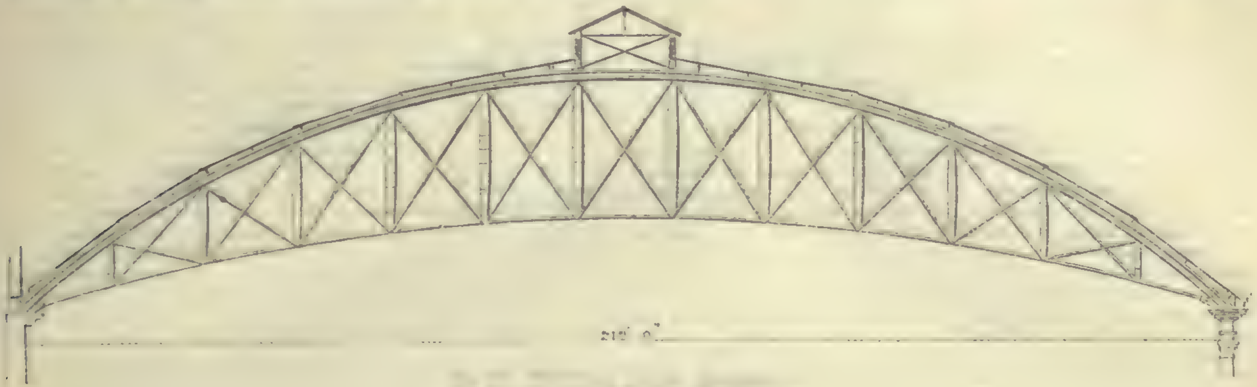


Fig. 27.—New Street Station, Birmingham.

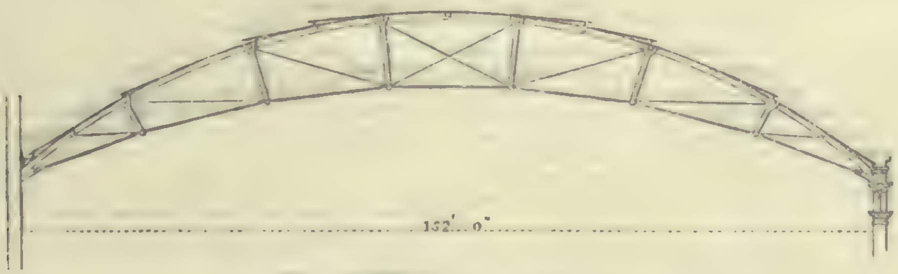


Fig. 28.—Lime Street Station, Liverpool.

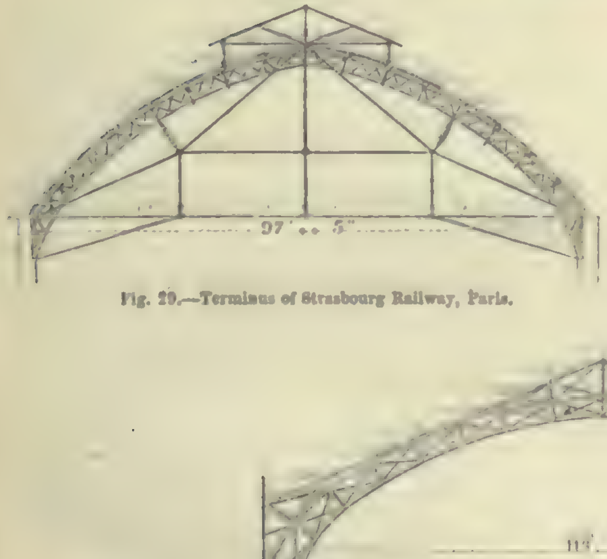


Fig. 29.—Terminus of Strasbourg Railway, Paris.

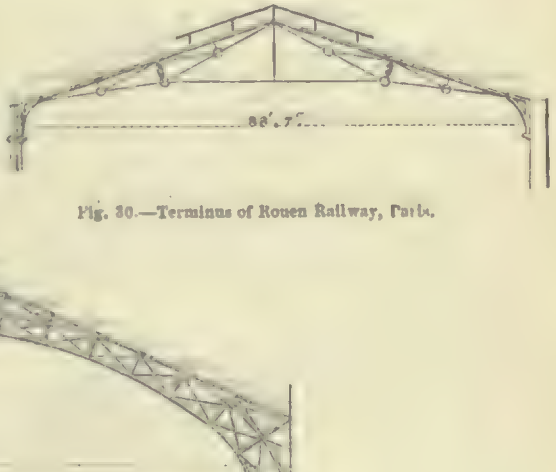


Fig. 30.—Terminus of Rouen Railway, Paris.

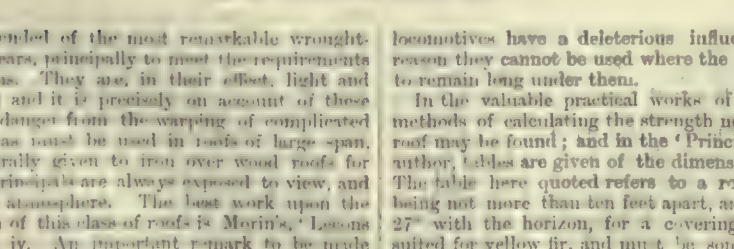


Fig. 31.—Entrepôt des Marais, Paris.

Some illustrations are appended of the most remarkable wrought-iron roofs executed of late years, principally to meet the requirements of the railway communications. They are, in their effect, light and elegant, even though costly; and it is precisely on account of these artistic qualities, and of the danger from the warping of complicated assemblages of timber, such as must be used in roofs of large span, that the preference is generally given to iron over wood roofs for railway sheds, wherein the principals are always exposed to view, and to the direct action of the atmosphere. The best work upon the strength and the construction of this class of roofs is Morin's, 'Leçons de Mécanique Pratique,' vol. iv. An important remark to be made with respect to these iron roofs is that the steam and smoke from the locomotives have a deleterious influence upon them; and for this reason they cannot be used where the locomotives in steam are likely to remain long under them.

In the valuable practical works of Nicholson, Tredgold, &c., the methods of calculating the strength necessary in the various parts of a roof may be found; and in the 'Principles of Carpentry,' by the latter author, tables are given of the dimensions suitable for different spans. The table here quoted refers to a roof similar to *fig. 7*; the trusses being not more than ten feet apart, and the pitch at an angle of about 27° with the horizon, for a covering of slates. The scantlings are suited for yellow fir, and must be somewhat increased for timber of inferior quality.

Span.	Tie-beam.	King-post.	Principal Rafters.	Braces.	Purlins.	Common Rafters.
Feet.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
20	9½ × 4	4 × 3	4 × 4	3½ × 2	8 × 4¾	3¼ × 2
22	9½ × 5	5 × 3	5 × 3	3¾ × 2½	8½ × 5	3¾ × 2
24	10½ × 5	5 × 3½	5 × 3½	4 × 2½	8½ × 5	4 × 2
26	11½ × 5	5 × 4	5 × 4½	4½ × 2½	8¾ × 5	4¼ × 2
28	11½ × 6	6 × 4	6 × 3½	4½ × 2½	8¾ × 5½	4½ × 2
30	12½ × 6	6 × 4½	6 × 4	4¾ × 3	9 × 5½	4¾ × 2

For the strength of different materials, under various circumstances, the reader may consult Materials, Strength of. As a general remark, it may be observed that oak, when exposed to tension, is weaker than fir, and is therefore less adapted for ties. Being, however, less compressible, it is usually preferred for rafters, straining pieces, and struts; but Tredgold observes that its greater tendency to warping in summer renders it less fit for rafters and purlins than foreign fir. Cast-iron is not much used in the framing of wooden roofs, excepting for shoes, king-post heads, bolt-heads, and collars at the feet of struts and straining pieces. Wrought-iron is very useful for straps and fastenings, and also for ties and trussing-posts; but care is always necessary to guard against imperfections, which are more likely to pass unobserved than in wood. Wherever iron is applied, provision should be made for its expansion and contraction, and it is desirable to protect it from oxidation by painting. Though iron is far stronger for its size than any kind of timber, it is neither so strong nor so cheap as yellow fir, *weight for weight*, provided the spans of the roofs are moderate.

The joints in the frame-work of a timber roof are of various kinds according to the nature of the strain they have to resist. They should be formed with great care, and with due regard to such probable changes of form as all constructions of timber are liable to from shrinking and warping. *Cocking* or *cogging* is the name given to that kind of joining in which one piece of timber, in a state of tension, is so attached to another that it cannot be drawn away without one piece breaking. *Figs.* 32 and 33 represent two methods of cocking the ends of tie-beams on the wall-plates, giving a plan and elevation of each. In both figures *a* represents the beam, and *b* the wall-plate. In the first plan, which was formerly much practised, the contraction of the dovetailed end of the beam would allow it to be drawn considerably out of its place, and would therefore permit the walls to spread: but in the second the amount of contraction is diminished, owing to the small width of the rectangular tongue that enters the tie-beam, while its position is such as to prevent the beam being drawn out of its place beyond the actual extent of the contraction of the tongue. The shrinking of the joggles of king-posts and queen-posts is often productive of serious derangement, a circumstance greatly in favour of the substitution of iron for wood for such parts, especially in large roofs. This inconvenience is sometimes avoided by making the upper ends of the principal rafters abut immediately upon each other, as represented in *fig.* 12. A similar arrangement is made, in some cases, where wooden king-posts are used, the king-post and rafters being strapped together with iron. The sinking of a roof, particularly if it be of low pitch, is very injurious to the mortise-and-tenon joints of the struts and rafters, by throwing the strain on the shoulders of the tenons in such a way as to break off the tenons or splinter the wood. To guard against such injuries, it has been proposed by M. Perronet, a French engineer, instead of making the tenons and joggles square, to form them into circular arcs, the centres being at the opposite end of the strut or rafter. This plan appears worthy of general adoption, as it allows the joints to accommodate themselves to changes of form without injury. All the timbers of a roof are usually fitted and framed together on the ground, and taken to pieces again before being elevated to the building.

Fig. 32.

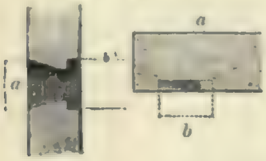
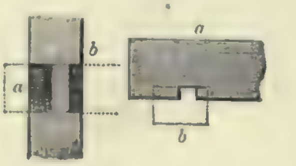


Fig. 33.



Allusion has been made in a previous column to the various materials used for the covering of roofs, with reference to the different degrees of inclination suitable for them. Thatched roofs have been considered by some to maintain the most equable temperature in the buildings covered by them, keeping out alike the extreme heat of summer and cold of winter. They are objectionable on account of their harbouring vermin, being easily damaged by wind, and dangerously combustible. The frequent repairs required make thatch also an expensive material. Besides straw, reeds and heath are sometimes used for thatching, and possess the advantage of greater durability. Tiles admit heat and moisture more than good slates. Pantiles, having no holes for nailing through, are simply hung, by ledges, upon laths nailed to the rafters. Plain tiles, laid in mortar, and over-lapping, so as to be of double thickness everywhere, make a very good though heavy covering. Tiles of a peculiar form, called *hip-tiles*, are used for covering salient angles; and *gutter-tiles*, which are similar to them, but placed with the concave side upwards, in the valleys or receding angles. Slates are laid in various ways. They are sometimes nailed down on a close boarding; or, if large, on *battens*, or pieces of wood from two and a half to three inches wide, and three-quarters of an inch to an inch thick, which are nailed to the rafters at intervals regulated by the length of the slates. Lozenge-shaped slating is occasionally used, and has an ornamental appearance, but is easily injured, as there is but one nail through each slate. It is always laid on boarding. For what is called patent slating the best large slates are selected, and fixed without either boarding or battening, the common rafter being placed at such a width as to come under the joints. The slates are screwed down, the courses over-lapping about two inches. The meeting joints are covered by fillets of slate about three inches wide, set in putty, and screwed down; and the hips and ridges are sometimes covered in the same manner, though it is best in all such cases to use lead. Patent slating, when well executed, is water-tight with as low a slope as one in six. In some districts laminæ of stone are used in lieu of slates or tiles. Shingles, which are like slates, but made of wood, were formerly much used in covering pyramidal steeples, and in roofs of steep pitch. They are still used in the United States, and are usually laid on boarding, in a similar manner to common slates.

Sheets of metal are very convenient for covering domes, and curved or angular surfaces generally; and also for flat roofs, or such as have too little slope for slating. Lead is the most common material for such purposes, though copper, iron, tinned iron, and recently zinc, are also used. Lead terraces or flats are commonly laid on boarding or plaster. The joints are sometimes soldered, but the most approved method is to roll or wrap the edges into each other, making allowance for expansion and contraction. A fall of a quarter of an inch in a foot is sufficient for surfaces covered with sheet metal.

Cements of various kinds have been applied to the formation of roofs, and in some cases with success, though they have often been found to crack, and thereby become permeable to water. Mixtures of tar with lime, sand, gravel, ashes, &c., have been recommended; and asphalte has been applied to this purpose, apparently with great advantage. Compositions of tar, resin, and similar substances, spread upon sheets of coarse paper, have also been used.

(Nicholson, *Architectural Dictionary*, *Practical Builder*, &c., &c.; Tredgold, *Principles of Carpentry*; Robison, *Mechanical Philosophy*; Rondelet, *l'Art de bâtir*.)

ROOT. The mathematical use of this term has gradually been extended, until it may be defined as follows: every value of an unknown quantity which satisfies a given equation is called a root of that equation. Thus, 2, 1, $1+\sqrt{(-3)}$ and $1-\sqrt{(-3)}$ are the roots, and all the roots, of the equation

$$x^4=5x^3-12x^2+16x-8,$$

since they are the only algebraical formulæ and arithmetical numbers which satisfy it. On this general use of the term root, see Theory of Equations and Involution.

The more common use of the term root is as follows: the seventh root of 8 is the incommensurable fraction whose seventh power is 8, or the solution of the equation $x^7=8$. There are altogether seven such solutions, one only arithmetical, the others of the form $a+b\sqrt{(-1)}$; the method of obtaining the arithmetical solution has already been discussed in the article Involution; the importance of the Square Root will justify its consideration in an article apart. We reserve for the present article the method of finding and using any root (in the common sense) of any algebraical quantity.

Every algebraical result is of the form $a+b\sqrt{(-1)}$ at widest, or may be reduced to that form. Here a and b are meant to be real algebraical quantities, that is, reducible to positive or negative whole numbers or fractions, commensurable or incommensurable. Thus, if $b=0$, we have the simple real quantity a; if $a=0$, we have the simple impossible quantity $b\sqrt{(-1)}$. It is indifferent, as to the present article, in what light the impossible quantity $\sqrt{(-1)}$ is considered; whether [Algebra] upon that extended system of definitions which makes it explicable and rational, or upon the more common system in which it is used without such explanation: for we are now merely considering all algebraic formulæ as results, subject to certain laws by which their use is to be regulated, and without any reference to interpretation. When we desire to consider only the arithmetical root of an arithmetical quantity, we shall use the symbols $\sqrt{}$, $\sqrt[3]{}$, $\sqrt[4]{}$, &c., but the exponential fractions $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, &c., will denote any one of the algebraical roots of a formula. Thus $\sqrt{16}$ means simply 4; but $(16)^{\frac{1}{2}}$ is an ambiguous symbol standing for either $+4$ or -4. And when we have an equation which presents an ambiguous formula equated to an unambiguous one, we mean that the unambiguous side of the equation is *one* of the values of the ambiguous one: in this sense $(1)^{\frac{1}{3}}=\frac{1}{2}(-1+\sqrt{(-3)})$. When we use the simple arithmetical symbol $\sqrt{}$ before an algebraical quantity, as in $\sqrt{(-3)}$, we merely mean to signify that the two values of $(-3)^{\frac{1}{2}}$ are distinguished into $+\sqrt{(-3)}$ and $-\sqrt{(-3)}$.

Let us now take a quantity of the form $a+b\sqrt{(-1)}$. Assume $r\cos\theta=a$, $r\sin\theta=b$, which gives

$$r=\pm\sqrt{(b^2+a^2)}\qquad\tan\theta=\frac{b}{a}.$$

Let us choose for r, which is called the *modulus* of the expression, the positive value $\sqrt{(b^2+a^2)}$. We can then always make the angle θ give the equation

$$a+b\sqrt{(-1)}=r\cos\theta+r\sin\theta\sqrt{(-1)}\,\ldots\ldots(1)$$

identically true. If a and b be both positive, θ must lie between 0 and a right angle, or between 0 and $\frac{1}{2}\pi$ [ANGLE]: if a be positive and b negative, θ must lie between $\frac{3}{2}\pi$ and 2π: if b be positive and a negative, θ must lie between $\frac{1}{2}\pi$ and π: and if both be negative, θ must lie between π and $\frac{3}{2}\pi$. Thus reducing angles to degrees and minutes,

$$2+3\sqrt{(-1)}=\sqrt{13}\left\{\cos\ 56^\circ\,19'+\sin 56^\circ\,19'.\sqrt{(-1)}\right\}$$
$$-2+3\sqrt{(-1)}=\sqrt{13}\left\{\cos 123^\circ\,41'+\sin 123^\circ\,41'\sqrt{(-1)}\right\}$$
$$2-3\sqrt{(-1)}=\sqrt{13}\left\{\cos 303^\circ\,41'+\sin 303^\circ\,41'\sqrt{(-1)}\right\}$$
$$-2-3\sqrt{(-1)}=\sqrt{13}\left\{\cos 236^\circ\,19'+\sin 236^\circ\,19'\sqrt{(-1)}\right\}$$

Generally, if a and b be positive, and if, returning to the arcual mode of measuring angles, θ be that angle which lies between 0 and $\frac{1}{2}\pi$ and has $b:a$ for its tangent, we must use θ for $a+b\sqrt{(-1)}$, $\pi-\theta$ for $-a+b\sqrt{(-1)}$, $2\pi-\theta$ for $a-b\sqrt{(-1)}$, and $\pi+\theta$ for $-a-b\sqrt{(-1)}$.

Again, since $\theta+2k\pi$ has the same sine and cosine as θ, when k is any whole number, positive or negative, if we take θ so as to satisfy (1), we find that the following is also satisfied:

$$a+b\sqrt{(-1)}=r\left\{\cos(\theta+2k\pi)+\sin(\theta+2k\pi).\sqrt{(-1)}\right\}\ldots.(2)$$

for all integer values of k positive or negative, but for no fractional value of k whatsoever. This and various other results of common trigonometry should be familiar to every student who attempts the present subject.

Common multiplication makes it obvious that

$$\left\{\cos x+\sin x.\sqrt{(-1)}\right\}\left\{\cos y+\sin y\sqrt{(-1)}\right\}=\cos(x+y)+\sin(x+y)\sqrt{(-1)}$$

for all real values of x and y; so that if we represent $\cos x+\sin x.\sqrt{(-1)}$ by ηx we have $\eta x\times\eta y=\eta(x+y)$. Now in BINOMIAL THEOREM it is proved that this equation cannot be universally true without giving as a consequence $(\eta x)^n=\eta(nx)$, for all values of n, whole or fractional, positive or negative. We have then

$$\left\{\cos x+\sin x\sqrt{(-1)}\right\}^n=\cos nx+\sin nx.\sqrt{(-1)}\ldots.(3)$$

an equation which goes by the name of De Moivre's Theorem. It is the key of the present subject.

Let it now be required to raise the nth power of $a+b\sqrt{(-1)}$, n being integer or fractional, positive or negative: this includes every case of raising a power, extracting a root, performing both operations, and taking the reciprocal of any result. Reduce $a+b\sqrt{(-1)}$ to its equivalent form $r\eta(\theta+2k\pi)$, or

$$r\left\{\cos(\theta+2k\pi)+\sin(\theta+2k\pi).\sqrt{(-1)}\right\},$$

whence $\left\{a+b\sqrt{(-1)}\right\}^n$ is $\left\{r\eta(\theta+2k\pi)\right\}^n$ or $r^n\eta(n\theta+2nk\pi)$, or $\left\{a+b\sqrt{(-1)}\right\}^n$

$$=r^n\left\{\cos(n\theta+2nk\pi)+\sin(n\theta+2nk\pi).\sqrt{(-1)}\right\},$$

in which r^n is found by purely arithmetical operation, and $\cos(n\theta+2nk\pi)$ and $\sin(n\theta+2nk\pi)$ by aid of the trigonometrical tables. So many distinct values as the variation of k enables us to give to $n\theta+2nk\pi$, so many values do we find of $\left\{a+b\sqrt{(-1)}\right\}^n$. Two angles are distinct when they are unequal, and do not differ by 2π or a multiple of 2π.

Firstly, let n be a whole number, positive or negative, then $2nk$ is always an integer even number, and there is only one value, namely,

$$\left\{a+b\sqrt{(-1)}\right\}^n=r^n\left\{\cos n\theta+\sin n\theta.\sqrt{(-1)}\right\}.$$

Next, let n be a fraction in its lowest terms, and, choosing an example, say $n=\frac{4}{5}$. Let us examine all the values of k, from $k=-5$ to $k=+5$, making $A_k=n\theta+2nk\pi$.

$$A_{-5}=\frac{4}{5}\theta-8\pi,\quad A_{-4}=\frac{4}{5}\theta-\frac{32}{5}\pi,\quad A_{-3}=\frac{4}{5}\theta-\frac{24}{5}\pi,$$
$$A_{-2}=\frac{4}{5}\theta-\frac{16}{5}\pi,\quad A_{-1}=\frac{4}{5}\theta-\frac{8}{5}\pi,\quad A_0=\frac{4}{5}\theta,\quad A_1=\frac{4}{5}\theta+\frac{8}{5}\pi,$$
$$A_2=\frac{4}{5}\theta+\frac{16}{5}\pi,\quad A_3=\frac{4}{5}\theta+\frac{24}{5}\pi,\quad A_4=\frac{4}{5}\theta+\frac{32}{5}\pi,\quad A_5=\frac{4}{5}\theta+8\pi.$$

Here it would seem as if from this set of the possible values of k, we get eleven distinct values of the fifth root of the fourth power of $a+b\sqrt{(-1)}$. But a moment's inspection shows that A_{-5}, A_0, A_5, are not distinct in effect, since they differ by multiples of 2π; neither are A_{-4} and A_1, nor A_{-3} and A_2, nor A_{-2} and A_3, nor A_{-1} and A_4. Also it will be found that for every value of k

$$A_{k\pm5},\ A_{k\pm10},\ A_{k\pm15},\ \&\text{c.},$$

are all angles which differ, each from its predecessor, by 2π; so that there are but five distinct angles in the whole series, which may be found by taking A_k, A_{k+1}, A_{k+2}, A_{k+3}, and A_{k+4}, with any value of k positive or negative. And generally, if n be a fraction whose denominator (when the fraction is reduced to its lowest terms) is q, it will be found that there are q distinct values of $\left\{a+b\sqrt{(-1)}\right\}^n$ and no more.

The most important cases are those in which $r=1$, or $a^2+b^2=1$, in which $\cos\theta+\sin\theta\sqrt{(-1)}$ may represent the expression. And of this particular case, the most important more particular cases are

$$\begin{array}{ll}\theta=0 & \cos\theta+\sin\theta\sqrt{(-1)}=1\\ \theta=\pi & \cos\theta+\sin\theta\sqrt{(-1)}=-1\\ \theta=\frac{1}{2}\pi & \cos\theta+\sin\theta\sqrt{(-1)}=\sqrt{(-1)}\\ \theta=\frac{3}{2}\pi & \cos\theta+\sin\theta\sqrt{(-1)}=-\sqrt{(-1)}\end{array}$$

Of these again, the two first are the most important.

Let $n=1:q$, and let the question be to find the q qth roots of 1. Putting unity in the form $\cos 2k\pi+\sin 2k\pi.\sqrt{(-1)}$, all these roots are the distinct values of $\cos\frac{2k\pi}{q}+\sin\frac{2k\pi}{q}\sqrt{(-1)}$ or $\left\{\cos\frac{2\pi}{q}+\sin\frac{2\pi}{q}\sqrt{(-1)}\right\}^k$.

Let $\cos\frac{2\pi}{q}+\sin\frac{2\pi}{q}.\sqrt{(-1)}=\alpha$, $\cos\frac{2\pi}{q}-\sin\frac{2\pi}{q}.\sqrt{(-1)}=\beta$.

Then $\alpha\beta=1$, as will be found by multiplication, and $\alpha^k=\beta^{-k}$: $\alpha^k=\alpha^{k\pm q}=\beta^{-k\pm q}$, since $\alpha^q=1$. Consequently, since the series of powers of α, positive and negative, are successions of qth roots of 1, the series of powers of β will be the same; and we may therefore select these roots at convenience from either series, or partly from one and partly from the other. Thus, if we would have the ten tenth roots of unity we may form them in pairs, as follows:—

$$\begin{array}{llll}\alpha^0\text{ and }\beta^0 & \text{give}\cos\frac{2.0\pi}{10} & \pm\sin\frac{2.0\pi}{10}\sqrt{(-1)} & \text{both}=1\\ \alpha^1\text{ and }\beta^1\text{ or }\alpha^9\ .\ . & \cos\frac{2\pi}{10} & \pm\sin\frac{2\pi}{10}\sqrt{(-1)} & \\ \alpha^2\text{ and }\beta^2\text{ or }\alpha^8\ .\ . & \cos\frac{4\pi}{10} & \pm\sin\frac{4\pi}{10}\sqrt{(-1)} & \\ \alpha^3\text{ and }\beta^3\text{ or }\alpha^7\ .\ . & \cos\frac{6\pi}{10} & \pm\sin\frac{6\pi}{10}\sqrt{(-1)} & \\ \alpha^4\text{ and }\beta^4\text{ or }\alpha^6\ .\ . & \cos\frac{8\pi}{10} & \pm\sin\frac{8\pi}{10}\sqrt{(-1)} & \\ \alpha^5\text{ and }\beta^5\text{ or }\alpha^5\ .\ . & \cos\frac{10\pi}{10} & \pm\sin\frac{10\pi}{10}\sqrt{(-1)} & \text{both}=-1\end{array}$$

Of these twelve forms, ten only are distinct, giving the ten tenth roots required. In this way the following theorems may be easily demonstrated.

1. The $(2m)$th roots of unity are $+1$, -1, and the $2m-2$ quantities contained in

$$\cos\frac{2k\pi}{2m}\pm\sin\frac{2k\pi}{2m}\sqrt{(-1)}$$

for all values of k, from $k=1$ to $k=m-1$, both inclusive.

2. The $(2m+1)$th roots of unity are 1 and $2m$ quantities contained in

$$\cos\frac{2k\pi}{2m+1}\pm\sin\frac{2k\pi}{2m+1}\sqrt{(-1)}$$

for all values of k, from $k=1$ to $k=m$, both inclusive.

3. If μ be one of the qth roots of unity, μ^2, μ^3, ... are also qth roots, but do not contain all the q roots, unless μ be made from a value of k which is prime to q. Thus, if $q=12$, and $k=1$, we get

$$a=\cos\frac{2\pi}{12}+\sin\frac{2\pi}{12}\sqrt{(-1)}$$

the list of roots is complete in 1, a, a^2, a^3, ... a^{11}, and a^{12} is 1, a^{13} is a, &c.

But if we make $k=8$, or take a^8 for μ, we have

$$\mu^2=a^{16}=a^4,\ \mu^3=a^{24}=1,\ \mu^4=a^{32}=a^8,\ \mu^5=a^{40}=a^4,\ \&\text{c.},$$

so that we get no roots from this series but a^8, a^4, 1, which are only the three cube roots of 1 (cube roots are among twelfth roots). But choose a^5 (5 is prime to 12) and its successive powers are a^5, a^{10}, a^{15} or a^3, a^{20} or a^8, a^{25} or a, a^{30} or a^6, a^{35} or a^{11}, a^{40} or a^4, a^{45} or a^9, a^{50} or a^2, a^{55} or a^7, a^{60} or 1, after which the series recurs in the same order.

4. If m be any factor of q, all the mth roots of unity are among the qth roots. Thus, if $q:m=v$, and if a be the first of the series of qth roots, the mth roots are a^v, a^{2v}, ... a^{mv} or 1. For $(a^v)^m=a^{vm}=a^q=1$, &c. All those powers of a which have exponents prime to q, may be called primary qth roots of unity: thus the primary 12th roots are a, a^5, a^7, a^{11}.

5. The qth roots of unity exist in pairs of the form $\cos\phi \pm \sin\phi \sqrt{(-1)}$. These pairs are a and a^{q-1}, a^2 and a^{q-2}, or a and a^{-1}, a^2 and a^{-2}, &c.

Let the question now be to find the qth roots of -1. If we now take

$$-1 = \cos(\pi + 2k\pi) + \sin(\pi + 2k\pi) \,.\, \sqrt{(-1)}$$

we have all the qth roots in the distinct values of the formula

$$(-1)^{\frac{1}{q}} = \cos\frac{(2k+1)\pi}{q} + \sin\frac{(2k+1)\pi}{q} \,.\, \sqrt{(-1)}.$$

Let $\alpha = \cos\frac{\pi}{q} + \sin\frac{\pi}{q}\sqrt{(-1)}$, then the qth roots required are α, α^3, α^5, ... α^{2q-1}, beginning with $k=0$, and ending with $k=q-1$. Thus, if μ be any one root, all the odd powers of μ (positive or negative) are also roots, but do not contain among them all the roots unless the value of $2k+1$, from which μ is derived, be prime to q. Thus if $q=15$, and if $\mu=\alpha^9$, we have (since $\alpha^{30}=1$)

$$\mu^3 = \alpha^{27},\ \mu^5 = \alpha^{45} = -1,\ \mu^7 = \alpha^{63} = \alpha^3,\ \mu^9 = \alpha^{81} = \alpha^{21},\ \mu^{11} = \alpha^{99} = \alpha^9\,;$$

so that we only get, from the powers of α^9, the distinct roots α^9, α^{27}, -1, α^3, α^{21}, which are also the fifth roots of -1. But if $2k+1$ be prime to q, all the qth roots of -1 may be obtained from μ. And if m be any factor of q with an odd quotient, all the mth roots of -1 are among the qth roots. Also these qth roots occur in pairs of the form $\cos\phi \pm \sin\phi\sqrt{(-1)}$, the pairs being α and α^{2q-1}, α^3 and α^{2q-3}, &c., or α and α^{-1}, α^3 and α^{-3}, &c.

Every qth root of -1 is one of the $(2q)$th roots of $+1$, and the $(2q)$th roots of $+1$ consist of all the qth roots of -1 and all the qth roots of $+1$.

The following equations will also be easily proved;

$$\{\sqrt{(-1)}\}^{\frac{1}{q}} = \cos\frac{(2k+\frac{1}{2})\pi}{q} + \sin\frac{(2k+\frac{1}{2})\pi}{q}\sqrt{(-1)}\,;$$

$$\{-\sqrt{(-1)}\}^{\frac{1}{q}} = \cos\frac{(2k+\frac{3}{2})\pi}{q} + \sin\frac{(2k+\frac{3}{2})}{q}\sqrt{(-1)}.$$

As it is not our object here to write on the applications of these formulæ, but only to supply an article of reference for those who may have forgotten or imperfectly learnt the groundwork of this very important branch of analysis, we finish here, referring to SERIES for such applications as fall within the plan of this work.

ROPE MAKING. A rope is a combination of fibres of hemp, or other material, so arranged as to form a flexible and tenacious cord or band; retaining, as far as possible, their collective strength. The name rope is generally confined to the larger descriptions of cordage, such as exceed an inch in circumference; though the principles of formation are much the same for cordage of every size.

If the fibres used by the ropemaker were of sufficient length, the most effectual way of obtaining their united strength would be to lay them side by side, fastened together at each end, so as to form a bundle or skein; but, as the fibres of hemp do not, on an average, exceed the length of 3½ feet, it becomes necessary, in order to obtain rope of greater length, so to twine them together that the strength of any single fibre shall be insufficient to overcome the resistance caused by the friction of those surrounding and compressing it; so that it will sooner break than be drawn out from the mass. This requisite entanglement is produced by twisting, which causes the fibres to compress each other; and it not only enables the ropemaker to produce cordage of any required length, but also, by making the rope hard and compact, increases its durability, and enables it to resist the penetration of water, which would rapidly impair its strength. While however some degree of twist is absolutely essential to the cohesion of a rope, any twist beyond that which simply prevents the fibres being drawn out without breaking, is injurious. A skein of fibres, or a rope, may be twisted so hard that any further attempt at twisting would break it; and such a skein will evidently have no power to support a weight, each fibre being already strained to the utmost extent that it will bear. In fact, whatever force is exerted by any fibre in compressing the rest, may be considered the same as a weight hanging on that fibre, and must be subtracted from its absolute strength before its useful effect can be ascertained; the available strength of a rope being the remainder of the absolute strength of its component fibres after deducting the force exerted in twisting them.

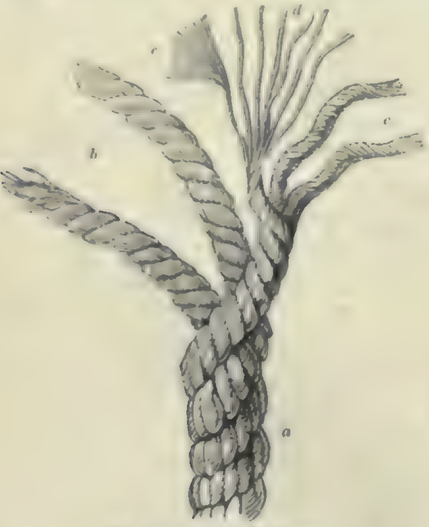


Fig. 1.—Analysis of a Rope.

Were a rope to be formed by simply twisting together, in one direction, the whole of the fibres of which it is composed, there would be nothing to prevent its untwisting as soon as left to itself. It is therefore necessary to twist the fibres in comparatively small portions, and so to combine these into a rope that the tendency to untwist in one part may counteract the like tendency in another. Thus the same force which would cause the component parts, if separate, to become loose or untwisted, is employed, when they are combined into a rope, to keep the whole firm and compact. This is illustrated in *fig.* 1, which may be considered as the unravelled end of a cablet or small cable. The cablet *a* may be untwisted into three smaller ropes, *b*; untwisting either of these in the opposite direction, we find it to consist of three smaller ropes, *c*; each of these may be untwisted into several small strings, *d*; and each of these consists of several distinct fibres of hemp, *e*. Thus several fibres form a *yarn*, several yarns a *strand*, three strands a *rope*, and three ropes a *cablet*.

With *fig.* 2 as an illustration, we may briefly describe the hand method of rope-making. The first process consists in twisting the hemp into thick threads, called rope-yarns. This process, which resembles ordinary spinning, is performed with various kinds of machinery. The common mode of spinning rope-yarns by hand is performed in the rope-ground, or rope-walk, an enclosed slip of level ground 600 feet or more in length. As many of the operations of a ropery would be impeded by wet weather, or by the unchecked heat of the sun, it is not unusual to cover the walk with a slight roof. At one end of this ground a spinning-wheel is set up, which gives motion by a band to several small rollers or whirls. Each whirl has a small hook formed on the end of its axis next the walk. Each of the spinners is provided with a bundle of dressed hemp, laid round his waist, with the bight or double in front, and the ends passing each other at his back. He draws out a sufficient number of fibres to form a rope-yarn of the required size; and, after slightly twisting them together with his fingers, he attaches them to the hook of a whirl. The whirl being now set in motion by turning the wheel, the skein is twisted into a rope-yarn; the spinner walking backwards down the rope-walk, supporting the yarn with one hand, which is protected by a wetted piece of coarse cloth or flannel, while with the other he regulates the quantity of fibres drawn from the bundle of hemp by the revolution of the yarn. The degree of twist depends on the velocity with which the wheel is turned, combined with the retrograde pace of the spinner. Great care is necessary in this operation to make the yarn of uniform thickness, and to supply the hemp equally from both sides of the bundle; because, if a considerable body of hemp be supplied to a yarn that is becoming too thin, it will not combine perfectly with it, but will form a loosely connected wrapper; and any irregularity in the last-mentioned particular will cause the fibres to bear the strain unequally.

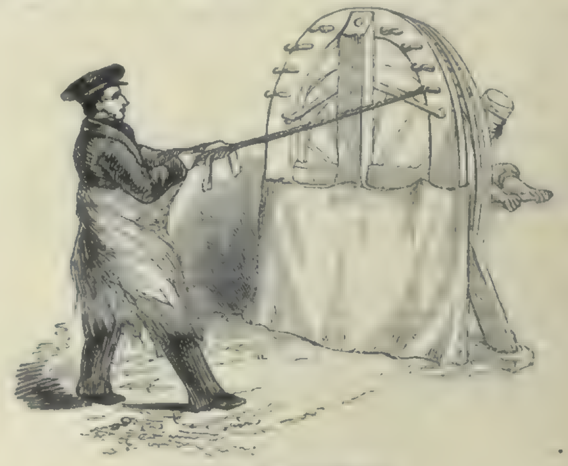


Fig. 2.—Rope-yarn Spinning.

The best mode of supplying the hemp is in the form of a thin flat skein. When the spinner has traversed the whole length of the rope-walk (or sooner, if the yarns are not required to be so long), another spinner detaches the yarn from the whirl, and gives it to a person who carries it aside to a reel; while the second spinner attaches his own hemp to the whirl-hook. The hemp, being dry and elastic, would instantly untwist if the yarn were now set at liberty. The first spinner therefore keeps fast hold of it all the while that the reeler winds it up, walking slowly up the walk, so as to keep the yarn equally tight all the way. When it is all wound up, the spinner holds it until another is ready to follow it on the reel. Sometimes, instead of being wound on a reel as they are made, the yarns are laid together in large hooks attached to posts at the side of the walk until about four hundred are collected together, when they are coiled up in a *haul* or skein, in which state they are ready for tarring.

The common size of rope-yarns is from one-twelfth to rather more than one-ninth of an inch diameter; 160 fathoms of white or untarred yarn weighing from two and a half to four pounds.

The next process is *warping* the yarns, or stretching them to a given length, in order that they may, when formed into a strand, bear the strain equally. When the rope is to be tarred, that operation is usually performed upon the yarns immediately after their being warped; as the application of tar to the yarns previous to their combination is necessary to the complete penetration of the whole substance of the rope. The most common method of tarring the yarns is to draw them in hauls or skeins through the tar-kettle by a capstan; but sometimes the yarns are passed singly through the tar, being wound off one reel on to another, and the superfluous tar being taken off by passing the yarn through a hole surrounded with spongy oakum. Great care is required in this process that the tar may boil neither too fast nor too slow, the common heat being from 212° to 250° Fahr. The degree of impregnation necessary depends on the kind of cordage; cables and water ropes needing a considerable quantity of tar, while for standing and running rigging it is sufficient that the yarns be well covered.

In making large cordage, it is not usual to twist together, at once, as many yarns as would suffice to form a rope of the required thickness; a suitable number of yarns, frequently from fifteen to twenty-five, are formed into a strand, and three or more such strands are afterwards combined into a rope. The twist of the strand is in an opposite direction to that of the yarns of which it is composed; in order that, as before mentioned, the tendency to untwist in the individual yarns may be counteracted, and taken advantage of to prevent the untwisting of the strand. In closing or laying the rope, three strands, or sometimes four, (in which case a small central strand or heart is added) are stretched at length along the walk and attached at one end to separate but contiguous hooks, and at the other to a single hook; and they are twisted together by turning the single hook in a direction contrary to that of the other three. A piece of wood called a *top* (see *fig.* 3), in the form of a truncated cone, is placed between the strands, and kept during the whole operation gently forced into the angle formed by the strands, where they are united by the closing or twisting of the rope. As the rope shortens in closing, one end only of the apparatus is fixed, the other being on a moveable sledge, whose motion up the ropewalk is capable of regulation by suitable tackle attached to it, or by loading it with weights. The top also is mounted on a sledge, for closing large cordage; and its rate of motion may be retarded, in order to give greater firmness to the twist of the rope. The art of the ropemaker, in this operation, consists in so regulating the various movements that the strands may receive separately at one end just as much twist as is taken out of them at the opposite end, by their twisting the contrary way in the process of combination.

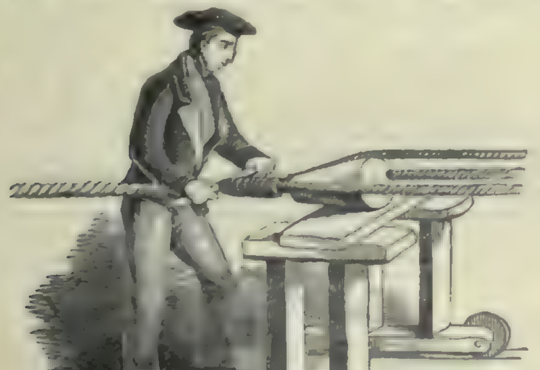


Fig. 3.—Laying a Rope.

Such is the method, more or less modified by the kind of machinery employed, of forming a *shroud-laid* or *hawser-laid* rope; and such appears to have been the whole process of rope-making until cordage of very large size was called for by the progress of navigation. In making such it was not found advisable to increase the number of yarns in a strand; it being difficult, when their number is very great, to throw an equal strain upon each, and thereby obtain their aggregate strength. To obviate this inconvenience, cables, or such large ropes as are said to be *cable-laid*, are formed by the combination of smaller ropes twisted round their common axis, just as shroud-laid ropes are composed of strands twisted round their common axis. As cable-laid ropes are harder and more compact than others, this mode of formation is adopted for ropes to be exposed to the action of water, even though their thickness may not be very great.

Ropes formed by plaiting instead of twisting are made use of for some purposes in which pliability is especially needed; they being more supple and less liable to entanglement than those of the ordinary make. Such ropes are preferred for sash-lines, clock-lines, &c., and generally where the rope has to pass over pulleys of small diameter.

Originally all the yarns composing a strand were selected of the same length. This arrangement was defective, as it is evident that when a number of yarns are stretched at length in a cylindrical mass, they will lie at different distances from the centre of the cylinder; so that, when twisted together, as all the yarns must form spirals of the same number of turns, those which are near the outside, forming spirals of large diameter, will be stretched to their full extent; while those near the centre, forming spirals of smaller diameter, will be less shortened by the process of twisting, and must therefore be more or less puckered up, according to their proximity to the centre of the mass. The first successful attempt to remedy this defect by varying the length of the yarns according to their position in the strand, was that under Captain Huddart's patent of 1793; since which time many further improvements have been effected in this essential point.

This brings us to notice briefly the application of machinery to rope-making, which may be said to have begun about the year 1783, and to have been the subject of numerous ingenious inventions since that date. One series of machines relates to the combining of the hempen fibres into yarns; another to the twisting of yarns into ropes; while the more complex kinds include both of these actions. Mr. Lang, of Greenock, was the first to produce successfully machine-spun yarns, intended to get rid of the irregularities and defects of those formed by hand. By his process the hemp is more completely heckled, or divided into fibres, than in the common mode of proceeding; and the advantage of each fibre being laid at full length in the yarn, instead of being doubled, as in hand-spinning, is ensured. By a modification of the usual process, the fibres of hand-spun yarns may be laid in at full length, instead of being doubled, as when they enter the yarn by their bight; but experiment has not shown any great advantage from such a mode of spinning. That some improvement in this operation was needful, may be inferred from the result of a comparison between Mr. Lang's machine-spun yarns and those of equal grist spun by hand; the result showing the strength of the former to exceed the latter by fifty-five per cent. Mr. Sherman, of Liverpool, patented a method of rope-making intended to obviate the necessity for a long shed or rope-walk. The machinery comprises rotating tables with hollow shafts or axes; spindles project from the surfaces of the tables; bobbins are mounted on the spindles; and hemp is wound on the bobbins. The number of bobbins depends on the number of yarns and strands. The ends of the yarns are passed through holes in a draw-plate beyond the hollow shaft of one table, then through the hollow shaft, then through another shaft; and so on. The yarn from each bobbin thus becomes twisted round that of the other bobbins on the same table; then round the similarly twisted strands of another series; and then of a third. The finished strand or rope is drawn from the tube of the last table, and is wound upon a reel ready for use. A modification of this planetary system, as the inventor calls it, suffices for twisting the strands into a rope.

Captain Huddart's rope-making machinery, above adverted to, is very ingenious. In order to get rid of the unequal strain upon the exterior and interior of a rope, Huddart saw that the outer yarns of every strand ought to be somewhat longer than the inner, to compensate for the greater circumference round which they have to turn. This he accomplished in a beautiful way. Bobbins are arranged in a skeleton frame, each poised on a pivot and loaded with yarn; the number of bobbins depends on the thickness of the strands to be made. The ends of all the yarns are passed through an equal number of small holes in a plate, and combined into one close group, which is slightly compressed by passing through a tube, and then wound on a reel. The mechanism between the plate and the reel rotates on a horizontal axis, thereby imparting a twist to the assemblage of yarns. The free rotation of the bobbins, the arrangement of the holes in the plate, the position of the tube, and the velocity of revolution—all combine to produce a strand of any desired hardness of twist, without undue strain upon any of the yarns. The strand thus produced is a smooth uniform piece of cordage, varying in thickness according to the size of the rope to be made; for a 12-inch cable, the strand is about an inch thick and contains 80 yarns. Being worked by steam power and having facilities for renewing the bobbins as they are exhausted, this machine can produce a rope any length.

The strength of twisted cordage has been made the subject of numerous experiments. Réaumur, early in the last century, found that a well-made small hempen cord broke in different places with 58, 63, 67, and 72 lbs., its mean breaking weight being 65 lbs.; while the three strands of which it was composed bore 29¼, 33¾, and 35 lbs. respectively; so that the united absolute strength of the strands was 98 lbs., although the average real strength of the rope was only 65 lbs., showing a loss of strength from twisting equal to 33 lbs. It appears that the cord used by Réaumur was of very unequal quality, as another portion of it broke with 72 lbs., while its strands bore separately 26, 28, and 30 lbs.; which shows the diminution of strength from twisting to have been from 84 to 72 lbs., the loss being in this instance only 12 lbs. The later experiments of Sir Charles Knowles indicates a diminution of strength nearly equal in amount to the first-mentioned of Réaumur. He found a white or untarred rope of 3¾ inches in circumference break, on an average of several trials, with 4552 lbs.; while the aggregate strength of its yarns, which were 72 in number, and bore on an average 90 lbs. each, was 6480 lbs.; the loss being equal to 1928 lbs., or about 30 per cent. Duhamel endeavoured to ascertain what degree of twist would produce the most useful effect. He caused some ropes to be made, so that only one-fourth of the length of the yarns was absorbed in twisting, instead of the usual proportion of one-third. These ropes were tried in shipping, and found to be lighter, thinner, and more pliant than those of the ordinary make. The following statement shows the comparative strength of ropes formed of the same hemp, and the same weight per fathom, but twisted respectively to two-thirds, three-fourths, and four-fifths of the length of their component yarns :—

Degree of twist.	Weight borne in two experiments.	
⅔	4098 lbs.	4250 lbs.
¾	4850	6753
⅘	6205	7397

The result of these experiments led Duhamel to try the practicability of making ropes without any twist, the yarns being wrapped round to keep them together. These had great strength, but very little durability, the outer covering soon wearing off, or opening at bendings, so as to admit water, and occasion the rope to rot. But while such untwisted skeins of rope-yarns, or *salvages*, are unfit for most of the purposes to which cordage is applied, they are used with advantage for the tackle of great guns and some other purposes for which the greatest strength and pliancy are required. The usual reduction of length by twisting is one-third; this applies to *shroud* or *hawser*-laid ropes; those which are *cable*-laid are further shortened, so that 200 fathoms of yarn are required to make 120 fathoms of cable. Ropes formed in the common manner, with three strands, do not require a *heart*, or central strand; because the angles formed by the union of the three cylindrical strands are so obtuse that the pressure of the operation of laying or closing the rope causes the strands to fill them up completely; but when the number of strands exceeds three, a heart is essential to keep them equidistant from the axis of the rope, and to fill up the vacuity that would otherwise be left by their not meeting in the centre. The heart can however add very little to the strength of the rope; as its fibres lie much straighter than those of the outer strands, and, not being able to extend with them when the rope is stretched, are soon pulled asunder. The following simple rule for calculating the strength of ropes is given by Robison:—Multiply the circumference of the rope in inches by itself, and the fifth part of the product will express the number of tons the rope will carry. For example, if the rope be 6 inches in circumference, 6 × 6 = 36, the fifth of which is 7⅕, the number of tons which such a rope will sustain. The following rules for calculating the *weight* of cordage may also prove useful:—To find the weight of shroud or hawser-laid rope, multiply the circumference in inches by itself, then multiply the product by the length of the rope in fathoms, and divide by 420, the product will be the weight in cwts. Example: to find the weight of a 6-inch hawser-laid rope, 120 fathoms long, 6 × 6 = 36 × 120 = 4320, which, divided by 420 gives the weight of the rope, 10 cwt. 1 qr. 4 lbs. Again: to find the weight of cable-laid cordage, multiply its circumference in inches by itself, and divide by 4. The product will be the weight, in cwts., of a cable 120 fathoms long; from which the weight of any other length may be readily deduced. Example: required the weight of a 12-inch cable, 120 fathoms long; 12 × 12 = 144, divide by 4, and the product, 36, is the weight in cwts.

Mr. Chapman, master ropemaker at Deptford Dockyard, in a treatise recently published on this subject, gives the following names, lengths, and weights of certain kinds of rope or line as usually made in England :—

Kinds.	Length.	Weight.
Deep sea lines	120 fathoms	36 lbs.
,,	,,	34
,,	,,	32
,,	,,	28
Hand lead lines	20	4
Hambro' lines, 12 threads . . .	28	3
,, 9 ,,	,,	2¼
,, 6 ,,	,,	1½
Fishing lines	25	1
,,	,,	¾
,,	,,	½
,,	,,	¼
Samson lines	30	1½
,,	,,	1¼
,,	,,	1
,,	,,	¾
Log lines	25	1 to 3
Marline	12 skeins	4
Sewing twine	24 ,,	8 to 9
Reefing twine	24 ,,	8 to 9

Much of the cordage used on shipboard requires the process of *serving* before it is fitted for its work. This consists in binding a smaller rope very tightly round a larger one, to preserve it from rotting after friction. It is done as shown in *fig.* 4, where a horizontally-stretched rope is being "served" or covered with spun yarns. A mallet, having a concave groove on the side furthest from the handle, is laid on the rope; two or three turns of spun yarn are passed tightly round the rope and round the body of the mallet. A boy passes a ball of yarn continually round the rope; while a man winds it on by means of the mallet, the handle of which serves as a lever to enable him to strain every turn as tightly as possible. The yarn thus appears like a screw whose threads pass almost transversely round the rope.

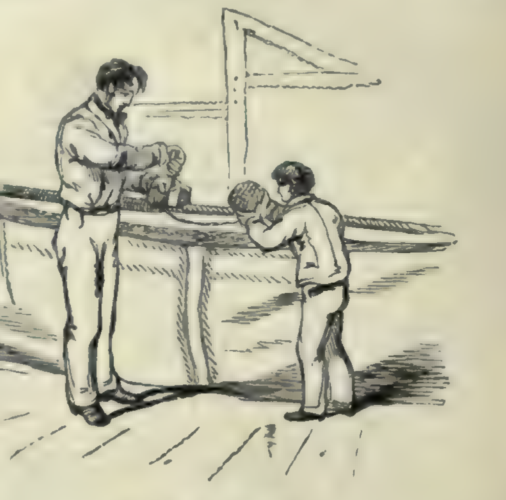


Fig. 4.—Serving a Rope.

All the ropes hitherto described are round or cylindrical; but *flat* ropes are also made, chiefly for mining purposes. They are either formed of two or more small ropes placed side by side, and united by sewing, lapping, or interlacing with thread or smaller ropes; or of a number of strands of shroud-laid rope similarly united. In either case it is necessary that the component ropes or strands be alternately of a right-hand and left-hand twist, that the rope may remain in a quiescent state. The latter method of making flat ropes was first patented by Mr. Chapman, in 1807; and he considered it to afford the strongest possible combination of rope-yarns, his belts or flat ropes appearing to be even stronger than *salvages* (which are skeins of rope-yarns without any twist) of the same number of yarns. This seeming inconsistency is occasioned by the imperfection of hand-spun yarns; because if each

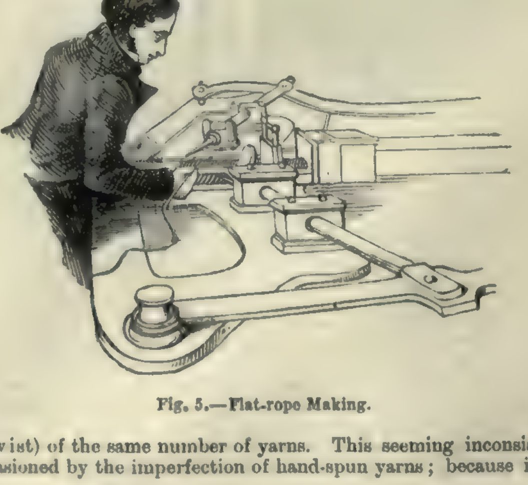


Fig. 5.—Flat-rope Making.

yarn bears its own strain unaided, it will break at its weakest part; whereas, if combined, the mean strength of each will be rendered available. Huddart's flat-rope machine, of more recent invention, is shown in part in *fig. 5*. Supposing four round ropes be needed to make one flat rope, four reels are so placed that the ropes can unwind from them with facility, and pass side by side through a steam-heated box, where the tar becomes a little softened, and the ropes more easily worked. They next pass through a groove or recess closed in tightly at top, bottom, and sides, except holes at the sides to admit large needles. A piercer, or sharp-pointed rod of steel, is then forced entirely through the whole of the four ropes, by leverage produced by steam power; and a man immediately passes a needle and thread through the hole. Two piercers are employed alternately, one on either edge, making holes as fast as two men can introduce needles and thread. The thread here spoken of is sometimes yarn as much as half an inch in thickness, requiring great force to draw it tightly.

Much attention has been devoted to the discovery of the best method of preserving ropes from decay, especially when exposed to the action of water. The operation of tarring, which has been almost universally practised for this purpose, effects it very imperfectly, and materially diminishes the strength of the cordage. Taking the mean of several experiments by Duhamel, it seems that untarred ropes bore a greater weight, by nearly 30 per cent, than those to which the tarring process had been applied; and he states that it is decided by experience that white cordage in continual service is one-third more durable than tarred, that it retains its force much longer when kept in store, and that it resists the ordinary injuries of the weather one fourth longer. Notwithstanding these facts, it is found that for cables and ground tackle, which are much exposed to the alternate action of water and air, tarring is a valuable preservative; though cordage that is only superficially tarred is said to be stronger than such as is tarred throughout, and better able to bear the alternations of wet and dry. The removal of the defects and bad qualities of common tar was the object of a patent taken out by Mr. Chapman. Unsuccessful attempts had been made to substitute oils and various fat substances, which would be insoluble in water, for tar; but they had been found to impede the operation of twisting. Chapman improved the ordinary tar, first, "by boiling the tar in water one or more times, each of which extracts a portion of its superabundant acid, and its mucilage, which contains a disengaged acid;" and, secondly, "by continuing these processes until the tar has thrown off a larger portion of its essential oil, and becomes more pitchy than usual; and, finally, by restoring the requisite plasticity through the addition of substances less injurious and less volatile, and therefore more continuous: namely, by the addition of suet, tallow, animal oils, or suitable expressed oils." Of the advantages attending this process, an idea may be formed from the subjoined statement of the relative strength of the cordage without any tar, with common tar, and with Chapman's purified tar. The rope contained twelve yarns in each strand; part was tried immediately, and the rest steeped in water for about three months, then removed to a foundry stove for three months, and finally kept at the ropery nine months; when another trial gave the following results:—

Description of Rope.	Portion of original strength retained.
White	5·7 per cent.
Common tarred	33·6 "
Tarred with purified tar	43·8

Sir Joseph Banks had some ropes tarred with *teak* tar, by way of experiment, and found them to be one-third stronger than those done with common tar. Tanning has been tried for the preservation of ropes, but apparently without realising any decided advantage. The solution employed in kyanising, and a solution of caoutchouc, have also been tried as preservatives; but common tar still continues to be the chief substance used for this purpose.

Mr. Chapman gives the following notice of the mode of classifying the work in her majesty's dockyards. Petersburg hemp is mostly used for cables and cablets; Italian hemp for bolt rope and breechings; and Riga hemp for all other cordage. To make Petersburg hemp into No. 20's, the hemp is given to the hatcheller in bundles of 70 lbs.; he takes out 7 lbs. of shorts, and gives 63 lbs. of heckled hemp to the spinner, who spins it into 18 threads of 170 fathoms and 3½ lbs. each. To make Riga hemp into No. 25's, the hemp is given to the hatcheller in bundles of 56 lbs.; he takes out 5 lbs. of shorts, and gives 51 lbs. of heckled hemp to the spinner, who spins 18 threads of 170 fathoms and 2⅚ lbs. each. In using Italian hemp, 16 lbs. of shorts are taken out of 112 lbs of hemp; and the remaining 96 lbs. are made up into bands of 1¾ to 3½ lbs. each, according to the size of the yarns to be made. Much old-fashioned routine still prevails in the royal dockyards, in defining exactly how many porters, parters, hatchellers, wheelturners, spinners, &c., shall be employed for each ton of hemp.

We have hitherto spoken only of hemp as the material employed; but several other kinds of vegetable fibre have been made use of in the manufacture of cordage; and some appear greatly to exceed hemp in strength. In a comparative trial made at Paris between ropes made of hemp and of the aloe from Algiers, the latter was found to bear 2000 kilogrammes, while the former, of equal size, bore only 400. Ropes have been formed also of long wool; but they are only about one-third as strong as the best hempen cordage of the same size. Ropes composed of fibres of hemp intermixed with threads of caoutchouc are very valuable for some purposes, owing to their superior strength and elasticity. Their power of bearing sudden jerks without injury is a highly important property. Such a rope was used with the grapnel or anchor of the great Nassau balloon, and was found to arrest the balloon without any unpleasant check when the grapnel caught. Ropes made of thongs of ox-hide twisted together are used in the rope-bridges of Peru, and for some other purposes. Coir or cocoa-nut fibre has lately been much used for this purpose, owing to the high price of Russian hemp; it wears well, weighs little, and is cheap; and is useful for hawsers and warps owing to its great elasticity.

Wire Ropes.—Iron is the substitute which is now engaging most attention. Ropes formed of this metal are found to effect a great saving of expense from their durability and superior lightness. From a paper communicated by Count Breunner to the British Association in 1838, it appears that such ropes had been introduced about seven years before, in the silver mines of the Harz Mountains, and had been found so advantageous as almost entirely to supersede flat and round ropes of hemp in the mines of Hungary, and most of those in the Austrian dominions. The count observes that these iron ropes are nearly equal in strength to solid bars of the same diameter, and equal to hempen ropes of four times their weight. One of them had been in use for upwards of two years without any perceptible wear, though a common flat rope performing the same work would not have lasted much more than one year. The diameter of the largest rope in ordinary use is one inch and a half, and it is composed of three strands, each containing five wires. Great care is observed in the manufacture of these ropes, that the ends of the wires may be set deep in the interior of the rope, and that two ends may not occur near the same part. In use, it is necessary that the ropes be wound on a cylinder of not less than eight feet diameter, and be kept well coated with tar, to prevent oxidation. In one case mentioned by Count Breunner, so great a saving of power was effected, that four horses were doing as much work with a wire rope as six with a flat hempen rope.

Prior to the date of this memoir, patents had been obtained in this country for the manufacture of wire ropes; and they have since been improved and acted upon. The wire ropes of Mr. Andrew Smith are formed in various ways, according to their intended use. For standing rigging straight untwisted wires are employed, bound round with cloth or small hempen cordage saturated with a solution of caoutchouc, asphaltum, or other preservative from rust. Flat ropes may likewise be made of straight wires, interwoven or wrapped with hempen yarn, or sewed between canvas, &c.; but the patentee prefers using them with a slight twist. Other ropes are formed much in the same way as those of hemp; the wires taking the place of rope-yarns, and being twisted into strands, and combined into ropes, both hawser-laid and cable-laid. The twisting should not be so hard as in hempen cordage; and all the wires must be protected by an anti-corrosive composition, or by coating with tin, zinc, &c. In a patent obtained by Mr. Newall of Dundee, for improvements in wire ropes, coating with the following mixture is recommended:—Tar, six parts; linseed oil, two parts; and tallow, one part: the whole being melted together, and applied while hot. In this patent it is proposed to twist wires round a core, either of wire, hemp cord, spun yarn, or other material, to form a strand; and to lay such strands round a similar core when there are more than three strands in a rope. For joining the wires, Messrs. Smith and Newall both recommend twisting their ends together for a few inches; and the latter also suggests the possibility in some cases, of welding them. Wire ropes may be very conveniently and firmly secured at their ends by passing them through the small end of a conical collar, and doubling up, or *upsetting*, the ends of the wires, which may then be welded into a solid mass, or secured by running melted brass or solder among them. The collars may then be attached, in various ways, to anything with which it is desired to connect the rope; or they may, as suggested in Newall's patent, be screwed together, so as to unite several lengths of rope. Iron is the material usually employed for wire ropes, but copper and other metals may also be used. The annexed table, showing the comparative size and weight per fathom for equal strength, gives the result of experiments with the wire ropes of Mr. Andrew Smith, and may serve to show their great superiority to those of hemp, which they surpass even in flexibility:—

Hemp Rope.			Patent Wire Rope.			Equal to a strain of	
Size.	Weight per fathom.		Size.	Weight per fathom.			
Inches.	lbs.	oz.	Inches.	lbs.	oz.	tons.	cwts.
3	2	4	1¼	1	4	2	10
4	3	15	1½	1	9	3	10
5	6	0	1¾	1	14	6	15
6	9	0	2	2	2	8	0
7	12	3	2¼	2	9	8	11
8	14	5	2½	4	1	9	18
9	19	6	3	5	4	15	6
10	25	0	3½	7	1	24	6
11	30	0	4	11	6	29	5
12	36	5	4½	15	12	35	4

Experiments were made at Liverpool in 1857, to find the relative strength of hempen rope and wire rope for the standing rigging of ships, as determined by the corporation testing machine at King's Dock. All the ropes were made by Messrs Garnock and Bibby, with equal care. The following results were obtained :—

3	inch galvanised iron wire rope bore a strain of . .	20 tons.
3	inch Manilla hemp rope ,, . . .	5
3	inch Russia hemp rope ,, . .	4
3	inch galvanised iron wire rope ,, . . .	16
3	,, ,, ,, . . .	8

The advantage of iron is here very obvious; indeed this metal is found to be, for a given strength, less heavy, less bulky, one-fourth cheaper, and less affected by the atmosphere, than hemp. Soft wire makes the most pliable rope for splicing; but hard wire is stronger. Three-fourths of all the ships now rigged at Liverpool are provided with iron wire standing rigging.

Some of the machines for making wire rope act in the following way. The wire is wound in bobbins mounted in frames set on the periphery of a larger frame like a cage. The cage revolves round an axis, on the bottom of which is a fixed spur-wheel; and the lower end of the vertical axis of each bobbin-frame carries a spur-wheel gearing into this. There is thus obtained a sort of 'sun-and-planet' motion, the cage carrying the bobbin round the central axis, and each bobbin-frame revolving also on its own axis. The wires, in their progress from the bobbins, pass through holes in the top of the central axis, and are there united to form the strand or rope. In Mr. Newall's patent of 1857, the strand-wire for electric cables is drawn through dies or between rollers after the twisting, to bring it to a close cylindrical form, and thereby aid the electric conduction.

The demand for wire rope being now very extensive, for shipping and for telegraphic cables, the patents are or have been regarded as valuable property. Mr. Newall's first patent, which expired in 1854, was a subject of many legal contests, arising out of infringements.

ROPES, RIGIDITY OF. [RIGIDITY OF ROPES.]

ROSA. *Medical Properties of.* Of the numerous species or varieties of this genus, three only are indicated in the 'Pharmacopœia' as the sources of the officinal articles; but a very considerable number of them contribute the different materials. Those indicated in the 'Pharmacopœia' are: the *Rosa canina*, or common dog-rose; *Rosa gallica*, the French or red rose; and *Rosa centifolia*, the hundred-leaved or cabbage-rose. Of the first, the so-called fruit (hips) is the officinal part. This is truly the enlarged persistent calyx, enclosing the real fruits, which are numerous small achenia, clothed, as well as the inside of the calyx, with silky hairs. The hairs and achenia are to be carefully removed, and the fleshy calyx beaten into a pulp, to which gradually thrice their own weight of white sugar is to be added. The employment of heat in the preparation of this conserve, though directed by the 'Pharmacopœia,' is better omitted. The pulp consists chiefly of malic and citric acids, in combination mostly with some salts, tannin, resins, a small quantity of volatile and fixed oils, fibre, and a large quantity of sugar. The action on the stomach is slightly refrigerant and aperient, its sweetness recommending it to children, and as a vehicle for other medicines. It is apt to candy or concrete by keeping. The fresh hips, freed from the fruits and hairs, bruised, and having a little sugar added, yield, by pouring warm water upon them, a cooling mildly astringent drink, which would be grateful to the poor suffering from autumnal fevers.

The petals of both the *Rosa gallica* and *R. damascena* are supplied to herbalists for medical and chemical purposes. The latter is most extensively cultivated at Mitcham for the London market. The buds are collected before they expand, and the calyx and lower part of the petals, termed claws, being cut off, they are quickly dried. If this last process be conducted slowly, it impairs both their astringency and fine Modena colour. Their astringency and odour are greatest when collected before the process of anthesis, or bursting of the anthers. About 2000 flowers yield 100 lbs. of fresh petals, which when dry weigh only 10 lbs. After drying the odour is faint, the taste bitter and astringent. As by exposure to the light and air they lose their fine colour, and soon become mouldy or worm-eaten, they must be carefully preserved in well-stopped bottles or canisters.

According to the analysis of Cartier, they consist of volatile oil, colouring matter, fatty matter, gallic acid, tannin, albumen, soluble salts of potash, insoluble salts of lime, silica, and oxide of iron. The tannic and gallic acids are the cause of the astringency, and also of the dark colour, which results on adding a solution of any salt of iron to an infusion of roses, and of a slight precipitate when a solution of gelatine is added to the infusion. The property of forming a black compound with iron is taken advantage of by beating the petals with cloves and other spices in an iron mortar, till a thick black paste is formed, which hardens on exposure to the air, and is then polished or turned, so as to form the perfumed beads for necklaces or rosaries. The petals of R. centifolia are often preferred. The exact nature of the colouring principle has not been ascertained, but it is not owing to oxide of iron, as the quantity of iron is much greater in white than red roses, Cartier having obtained from 1000 grains of white roses 99 grains of ashes, containing 12·4 of iron, while a similar quantity of red roses yielded only 50 grains of ashes, containing only 4 grains of iron.

The petals of the *Rosa damascena* are the most laxative, except perhaps the *R. semperflorens*, but it is seldom that they are used as aperients, though the petals of the *R. gallica* are formed into a confection which has the advantage over that of the *R. canina*, inasmuch as it neither candies nor becomes mouldy. In forming this or the other preparations, a stone (not an iron) mortar must be used. The chief employment of the conserve of the Gallic rose is as a vehicle for other medicines and as the basis of blue pill.

The infusion of roses is made by pouring boiling distilled water on the petals, and adding dilute sulphuric acid, which are allowed to macerate for six hours, and when strained, refined sugar is to be added. The vessel in which this process is conducted should not be glazed with lead. By this means is obtained an elegant, fragrant, and mildly astringent tonic and refrigerant liquid, which is of great utility, either alone, especially to check the wasting perspirations of consumption, or as a vehicle for most salts which are formed with sulphuric acid. It is likewise employed as a gargle, alone, or with various adjuncts, one of the best of which is the mel rosarum, or honey of roses, made with the petals of this kind of rose. A syrup is sometimes made with them, which is only used to sweeten and colour other medicines.

The *Rosa centifolia*, hundred-leaved rose, especially the variety of it termed the *Provence* or *cabbage rose*, is cultivated both on account of its exquisite perfume and the uses to which it, with its products, can be applied. The petals are the officinal article. They are directed to be collected when the flower is full blown; and to be plucked off, not allowed to fall off. It is better to collect them before the flower is fully expanded, as the odour rapidly diminishes as the anthesis proceeds; 100 parts dry into 18 only. They are to be dried in the open air, and not in an oven, as desiccation impairs their fragrance, while it heightens that of the *R. gallica*. Their odour is said to be singularly exalted by iodine. When dried, they are of a pale red, with a faint rose odour, and an astringent taste. They easily part with their colour, and are therefore to be protected from air and light: if salted, they may be preserved unimpaired for years. With the addition of salt, pepper, and cloves, they are used to form the rose-pots which adorn the apartments of the rich, but which may equally be made to contribute to the enjoyment of the poor, as the expense of this perpetual feast is so small as not to be felt by the poorest occupier of a room. The colouring matter extracted by alcohol furnishes a most delicate test for the presence of alkalies.

A syrup is also made of this sort, but the chief use of it in England and France is to yield by distillation rose-water, the medical properties of which are too slight to merit further notice here. That to which spirit of wine has been added is unfit for medical purposes. In hot countries a large quantity of volatile oil is elaborated by the flowers of this and several other species, such as the *Rosa moschata*, *Rosa damascena*, and in Italy the *Rosa sempervirens*, which constitutes the *athar*, *ather*, *attar*, *utter*, or *otto* of roses. [ATTAR OF ROSES.]

(Pereira's *Materia Medica.*)

ROSARY. [BEADS.]

ROSE, *Culture of the.* To obtain roses in their full perfection they require a situation open to the south, and free from buildings, trees, and the effects of smoke. They must also be sheltered from the wind. The tenderer sorts should be trained on a wall; the hardier dwarfs in beds or on the lawn, and standards arranged in lines along the walks. In planting, care should be taken to give room for the roots. A hole three feet in diameter and two feet deep should be filled with rich loamy soil, or a mixture of leaf mould, or rotted cow or pig manure, the straggling rootlets removed, and the plant be fixed in the centre, supported by a stake to prevent it being loosened by the wind. November and December are the general months for planting, but February is perhaps better in moist soils if the holes are made previously and exposed to a winter's frost. Standards should be at least three feet apart, dwarfs may be one-third closer. When planting in pots, the same soil should be prepared, taking care to have the bottom of the pot well supplied with broken crocks, and, to ensure sufficient drainage, the hole for the pot should be made of such a size and such a depth, that on pressing the pot into it, till about an inch below the surface, it may drive some of the side soil down so as to form a shoulder, and leave a vacancy of an inch or two below the pot. This not only ensures drainage, as the plant requires good watering, but is less likely to attract the roots to the adjacent soil. Roses are all the better for such surface-manuring during the autumn, either with compost of night-soil, or guano and wood ashes.

In raising roses from seed, the hips, gathered when quite ripe, should be kept dry and whole till February, then broken and sown in a seed-pan about 8 or 9 inches deep, filled with rotten manure mixed with sandy loam or peat, covering the seed with about half an inch of the mould. Care must be taken to guard the seed from the attacks of mice; this is best done by covering with a wire web, which also preserves the pan moist. Water occasionally, and the young plants will begin to appear in April or May. After having made three or four leaves, pot them in small pots, and in about a month they will be fit to remove to the border; and the free-growers by August will have made shoots sufficient to take buds from. The stocks must be cut down and budded, and they will then flower in the following summer if left unpruned.

Summer and autumnal roses are propagated by layers, cuttings, budding, and grafting. These operations are the same for the rose as for many other plants, and the budding is performed with even more facility than with many other plants, as the bark opens and closes firmly. Strong plants are also raised by budding on the roots, which are divided from the parent stem, and by this practice a year is gained for bushes flowering on their own roots.

The usual stock for grafting on is the common briar; but almost any rose of a hardy nature will afford stocks for a more valued variety, where the stocks are not required of a great height for standards, and one of the most favoured is the Minetti, a variety introduced from Italy, which has the advantage of not throwing up suckers. Of other roses, from which stocks are wished for, the suckers may be allowed to spring. The forcing of roses for early show or for the greenhouse depends on the same principles as other plants—a somewhat earlier budding, protection from cold, and moderate heat applied in the early spring.

The varieties are now almost endless, and every season produces new ones. All the chief families are mentioned under Rosa, in the Nat. Hist. Div., and a list of the principal varieties will be found in Rivers's 'Rose Amateur's Guide,' last edition.

ROSE ENGINE TURNING. [Turning.]

ROSEO-CHROME. [Chromium.]

ROSEO-COBALTIN. [Cobalt. *Ammoniacal Compounds of Cobalt.*]

ROSETTA STONE is the name given to a stone in the British Museum, which was originally found by the French in 1799 among the ruins of Fort St. Julien, which is near the Rosetta mouth of the Nile. It was delivered up to the British on the capitulation of Alexandria, and was brought to England in the year 1802. This stone, which is a piece of black basalt, contains parts of three distinct inscriptions: the highest on the stone is in what we generally call hieroglyphic; the second is in that character commonly called the "enchorial," or "the characters of the country;" and the third, which is in Greek, declares, at the end, that the decree which this stone contains was cut in three different characters, the "sacred characters," "those of the country" or the "enchorial," and the "Greek." In its present state the stone is much mutilated, chiefly at the top and at the right side. Its greatest length, in its present condition, is about three feet, measured on the flat surface which contains the writing; its breadth, which in some parts is entire, is about two feet five inches. A large part of the hieroglyphic inscription is broken off, but it probably contained in its entire state about twenty or at the utmost twenty-one lines; the enchorial or second inscription consists of thirty-two lines, but the beginning of the first fifteen lines are wanting, and the Greek text contained, when entire, fifty-four lines, but the end of it is at present mutilated. We learn from the Greek text that the Rosetta stone was erected in the reign of Ptolemy V., Epiphanes, and probably about B.C. 196. Epiphanes succeeded to the throne on the death of his father Philopator, B.C. 205, when he was a child only four or five years old. In this monument the acts done during the prince's minority are attributed to him, and he is commended for his piety, his liberality to the temples, his remission of the arrears of taxes and diminution of the imposts, his victories over the rebels, and his protection of the lands by dams against the inundations of the Nile.

It appears to have been placed in a temple dedicated by Necho to the god Tcum, the setting sun. The Rosetta stone was the key to the interpretation to the hieroglyphs, the first attempts of De Sacy to decipher the demotic or enchorial having been followed by the more successful results of Young and Champollion, in deciphering the hieroglyphic text. Lately a critical translation of the hieroglyphical portion has been made by M. Brugsch.

A critical examination and restorations of the Greek text have been made by Ameilhon, Heyne, Villoison, Drumann, Porson, and Letronne. The enchorial text has been also published and translated by Young and Brugsch. As the inscriptions are paraphrases and not literal translations, and the hieroglyphical portion is much mutilated, it does not add a great deal to the hieroglyphical vocabulary. [Hieroglyphics.] (Brugsch. H., 'Die Inschrift von Rosette,' fo. Berlin, 1850; 'Inscriptio Rosettana,' 4to, Berlin, 1851; Letronne, 'Inscription Grecque de Rosette,' 8vo, Paris, 1840.)

ROSICRUCIANS is the name of a secret society whose existence became first known to the public in the 17th century, by means of several publications which have been attributed to John Valentine Andreæ, a German scholar, born at Herrenberg, in the duchy of Würtemberg, in 1586, who, after studying at Tubingen, became a minister of the Lutheran church, and in course of time was made almoner of the Duke of Würtemberg and abbot of Adelberg. Andreæ died in 1654. He was a man of a mystical turn of mind, who had conceived the idea of effecting a general reform of mankind. He wrote many works, chiefly on mystic subjects. It is doubtful, however, whether those particular works which would establish his connection with the Rosicrucian Society are really his. The following are the titles of three of his works:—1. 'Eleucidarius Major, über die Reformation der ganzen weiten Welt, F. C. R. aus ihren chymischen Hochzeit,' 1617, in which there is a mixture of precepts of alchemy with maxims of ethics. 2. 'Fama Fraternitatis des löblichen Ordens des Rosenkreuzes,' Frankfort, 1617, in which there is a story of a certain Christian Rosenkreuz, a German noble of the 14th century, who, after travelling long in the East, returned to Germany, and there established a fraternity, or secret society, of a few adepts, under certain regulations, living together in a building which he raised under the name of Sancti Spiritus, where he died, at 106 years of age. The place of his burial was kept a profound secret by the adepts, and the society renewed itself by the admission of successive new members in silence and obscurity, according to the last injunction of its founder, who directed the following inscription to be placed on a door of Sancti Spiritus:—"Post CXX. annos patebo." 3. 'Confessio Fraternitatis Rosese Crucis ad Eruditos Europæ,' which is appended to the preceding, and in which it is stated that the order does not interfere with the religion or polity of states, but only seeks for the true philosophy; that many absurd fables have been told of the fraternity, either by its enemies or by fantastic people. It states also that once a year the members are to meet at appointed places to converse together upon secret matters, and that new members are to be admitted to supply the place of those who are deceased, and to work for the common purpose of the order, giving no clue however for discovering what that purpose was. In fact the secret, if secret there was, has been effectually kept to the present day. The Rosicrucians have not been heard of as a separate order for a century past; but some have thought that they continued to exist under the name of the Illuminati, who were much talked of in Germany and France in the latter part of the 18th century; and a connection has been supposed by some writers to exist between the Rosicrucians and the Templars and Freemasons. The reader who wishes to investigate this obscure subject may consult F. Nicolai, 'On the Crimes ascribed to the Templars;' Chr. Murr, 'On the True Origin of the Rosicrucians,' 1803; and J. G. Buhle, 'Ueber den Ursprung und die vornehmsten Schicksale der Orden der Rosenkreuzer und Freymaurer,' Göttingen, 1804.

ROSIN. [Resins.]

ROSMARI'NUS OFFICINA'LIS, *Rosemary*, a term which is apt to lead to the confounding of Rosemary with the Ledum palustre or wild marsh-rosemary, which has very different and even dangerous properties. Genuine rosemary is a shrub, a native of the south of Europe, Asia Minor, and China. To the bees feeding on the flowers, the flavour of Narbonne honey is said to be owing. The officinal part is the top or upper part of the twigs. The flowers were termed *Anthos*, being so highly esteemed, as if it were the flower of flowers. This name it is necessary to know, as many of the earlier preparations come under it, rather than under rosmarinus. The leaves are about an inch long, linear, slightly revolute at the margins, dark green and reticulate on the upper surface, hoary and white on the under. The leaves and calyces of the flowers have a strong, penetrating, aromatic odour, which is rendered stronger by bruising them; and a bitter, burning, camphor-like taste. They owe this to the presence of tannic acid, bitter matter, perhaps resin, and especially to a volatile oil, of which one drachm may, by distillation, be obtained from one pound of the leaves.

Oil of rosemary (Oleum Rorismarini, or Ol. Anthos) is chiefly prepared in Spain and the south of France, by distillation of the leaves and flowers. At first it is nearly transparent and very limpid, but by time it becomes both yellowish and thicker. It possesses the strong penetrating odour of rosemary, with a camphor-like intermixture, and a burning taste. It has an acid re-action. The specific gravity varies with the purity and age of the specimen; it is commonly 0·91, but by rectification with alcohol it is brought to 0·89 or 0·85. It mixes with alcohol of ·83 in every proportion. By shaking with potass, or by the evaporation and absorption of oxygen which time effects, it deposits a stearopten, or rosemary-camphor, to the extent of a tenth part. Hydrochloric acid gas blackens it, but does not form an artificial camphor. With iodine it partially explodes.

The oil of rosemary of commerce is an artificial preparation of oil of turpentine distilled with rosemary; it is also adulterated with spike oil, obtained from the Lavandula Spica. This may always be distinguished from the genuine by not reddening litmus-paper.

Rosemary possesses valuable stimulant and carminative properties; but it is chiefly employed as a perfume, entering into the composition of the Queen of Hungary's Water, Eau de Cologne, and aromatic vinegar. Properly diluted it forms a useful evaporating lotion. It is also used in preparations for promoting the growth of hair and preventing baldness.

ROSOLIC ACID was discovered by Runge in 1834, and was so called from the rosy-red colour of its salts. It is formed occasionally in gas works when Carbolic Acid is exposed to the air in contact with lime. Rosolic acid may be artificially prepared by heating together a mixture of manganate of soda and crude carbolic acid. On decomposing the dark red rosolate of soda by hydrochloric acid, the rosolic acid is precipitated in resinous flakes which unite to an amorphous mass.

Pure rosolic acid is a dark green lustrous resin. Its powder is of a bright red colour, soluble in ether, alcohol, creasote, the alkalies, and in concentrated acids. Its acid characters are very feeble, and its compounds unstable. Were it less fugitive it would be valuable as a dyeing agent.

Rosolic acid has lately been examined by Hugo Müller and by Angus Smith, with the following results in regard to per-centage composition:—

	Smith.	Müller.
Carbon	70·837	75·92
Hydrogen	5·814	5·83
Oxygen	23·349	18·25
	100·000	100·000

At present the data are insufficient for the calculation of its formula.

ROSTRUM, or, more properly, ROSTRA, was a platform or elevated space of ground in the Roman forum, from which the orators used to address the people, and which derived its name from the circumstance that after the conquest of Latium the beaks (rostra) of the Antiatian ships were affixed to the front of it. (Liv., viii. 14.) The rostra was between the Comitium, or place of assembly for the Curiæ, and the Forum, properly so called, or place of assembly for the Comitia Tributa. Bunsen, in his work on the Roman Forum, quoted by Arnold ('History of Rome,' vol. ii., p. 165), judging from the views of the rostra given on coins, supposes that "it was a circular building, raised on arches, with a stand or platform on the top, bordered by a parapet, the access to it being by two flights of steps, one on each side. It fronted towards the comitium, and the rostra were affixed to the front of it, just under the arches. Its form has been, in all the main points, preserved in the ambones, or circular pulpits, of the most ancient churches, which also had two flights of steps leading up to them, one on the east side, by which the preacher ascended, and another on the west side, for his descent. Specimens of these old pulpits are still to be seen at Rome, in the churches of S. Clement and S. Lorenzo fuori le Mure." The orators appear to have walked up and down the rostra in addressing the people, and did not, like modern speakers, remain standing in one spot. Down to the time of Caius Gracchus even the tribunes in speaking used to front the comitium; but he turned his back to it, and spoke with his face towards the forum. (Niebuhr, 'History of Rome,' vol. i., note 990; vol. iii., note 268.)

ROTATION (*Rota*, a wheel). The popular conception of a body in rotation is vague, except only in the case in which the rotation is made about an immoveable axis. This subject has accordingly been usually treated by mathematical methods; and mathematicians content with their results, and with their power of interpreting them, did nothing towards the improvement of the manner of presenting the elementary view of rotation. M. Poinsot first divested the subject of its previous complexity, in a Memoir read to the Academy of Sciences, May 19, 1834.

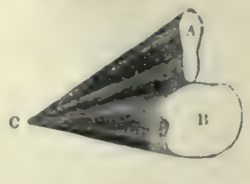
There is this parallel between the conception we form of the simple motion of a point and that of a solid body, namely, that each has a case of peculiar simplicity, by which others are rendered more easy to describe. A point may move in a straight line, or may preserve its direction unaltered; a body may revolve round a fixed axis, or each point may preserve its circle of revolution unaltered. But owing to the comparative simplicity of the motion of a point, it is easy [DIRECTION] to carry with us, when it moves in a curve, the idea of its still having a different direction at every point of the motion, namely, that of the TANGENT of the curve. It is not so easy to see that whenever a body moves about a fixed point, no matter how irregularly, there is always, at every instant of the motion, some one axis which is, for that instant, at rest. This notion of an instantaneous axis of repose, not continuing to be such for any finite time—answering to that of an instantaneous direction in curvilinear motion, which does not continue for any finite time to represent the direction—must be first distinctly formed, before any satisfactory account of the rotation of a body can be given.

Let us suppose a uniform sphere, with a fixed centre, but otherwise free to move in any way. Let a succession of forces act upon it, gradual or not, in such a manner that it will never move round one axis for any finite time during the continuance of their action. At a certain moment, let all the forces cease entirely, leaving the sphere to itself. It is easy enough to see that from and after the moment of discontinuance, the sphere will move round an axis which remains unaltered. There must then, at the very moment of discontinuance of the forces, have been an axis which was for that moment at rest, namely, the axis on which the motion is to continue after the forces cease. In this way, knowing that curvilinear motion would become rectilinear the moment that the deflecting forces are removed, we may form an idea of the tangent of a curve, the line of direction for the time being.

One of M. Poinsot's remarkable propositions is the following:—Any motion of a system round a fixed point may be attained by cutting a cone (in the most general sense of the word) out of the body, with the fixed point for a vertex, and fixing in space another cone for it to roll upon, also with the fixed point for a vertex.

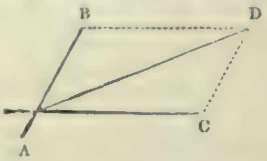
Thus if, in the adjoining diagram, the cone A be made to roll upon the cone B, both being supposed destitute of impenetrability, so that the contact of the curves of A and B can always be made, and if the system out of which A is cut be then restored (also without impenetrability), there will be a complete geometrical representation of one possible motion of the system about C. Moreover, there is no possible motion which might not be represented in the same manner by properly choosing the cones A and B, and the axis of repose for the instant is the line in which the two cones touch.

If we suppose no fixed point in the system, so that motion of translation, as well as of rotation, is possible, M. Poinsot has given another equally distinct notion of the state of the motion during an infinitely small time. The most simple notion which we can form of a combined translation and rotation is the screw-like motion, in which a uniform motion of translation is accompanied by a uniform motion of rotation round a line parallel to the motion of translation. M. Poinsot has shown that every motion of a system must be, at any one instant, either a simple motion of translation, or one of rotation, or the screw-like motion above described. That is to say, at every point of time in the motion of a system there exists a line (whether internal or external to the *material* system matters not, so long as they are immoveably connected) along which the system is at that instant sliding, while all the rest of the motion at that instant is simple rotation about that *slipping axis*.



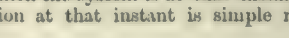
Let us now suppose a system to receive at the same time two motions, round two different axes of repose: that is to say, given two different motions, required the motion which will result from the two motions impressed on the system at once. There will be at the first instant an instantaneous axis of repose, which it is required to find. First let the two axes pass through the same point A (*Fig.* 1), and choose the angle B A C out of the four angles made by the two axes, in such manner that points of the system lying in the angle B A C would be elevated by the rotation round B A, and depressed by that round C A, or *vice versâ*. On the axes take A B and A C, lines proportional to the angular velocities about those axes, complete the parallelogram A D, and draw the diagonal A D. Then A D is the axis of repose at starting (which however it may not continue to be), and A D represents the angular velocity round that axis at starting, in the same manner as A B and A C represent the impressed angular velocities about A B and A C. [COMPOSITION.]

Fig. 1.



Next let the axes be parallel to one another, say perpendicular to the plane of the paper, passing through A and B (*Fig.* 2). If the rotations be such that A and B would both rise, or both fall, on the paper, each by the rotation about the other, take a point C in B A produced, nearest to the axis about which the angular velocity is greatest (say that of A), and such that C A is to C B as the angular velocity about B to the angular velocity about A. Then the axis of repose at starting is a line passing through C parallel to the former axes, and the angular velocity is the difference of the angular velocities about A and B, and in the direction of the greater. In this case the directions of the rotations about A and B [DIRECTION OF MOTION] are different. There is one remarkable case, namely, when the rotations about A and B are equal. In this case the rule would lead us to a rotation equal to nothing made about a point at an infinite distance—one of those extreme conclusions which require interpretation. The fact is that these two rotations give only a simple motion of translation = A B × Angular Velocity per second, and such as to make the system move upwards or downwards on the paper according as the separate rotations would make the points A and B move upwards or downwards. This particular case will be more intelligible when looked at with the help of the THEORY OF COUPLES.

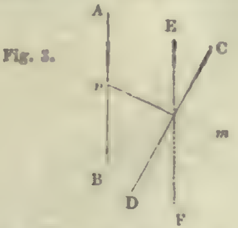
Fig. 2.



But if the rotations be in the same direction, so that A will be lowered and B raised, or *vice versâ*, each by the rotation about the other:—Take a point D, dividing A B so that A D is to D B as the angular velocity about B is to that about A. Then will the axis of repose at starting be a parallel drawn through D to the axes passing through A and B, and the angular velocity will be the sum of the angular velocities about A and B, its direction being that which lowers A on the paper and raises B, or *vice versâ*, according as is done by the given angular velocities.

Lastly, let the axes be neither parallel nor intersecting (*Fig.* 3), as A B and C D:—Through the point *m*, in which C D meets the common perpendicular, *m n*, draw E F parallel to A B, and at the instant at which the rotations round A B and C D commence, impress two equal and contrary rotations about E F, each equal to that about A B. These produce no effect, so that the composition of the four rotations gives the same result as that of the two. Now, as above stated, the rotation round A B, and its equal and contrary round E F, produce nothing but a motion of translation, while the remaining rotation about E F, compounded by the first rule with that about C D, gives what would be an axis of repose, if it were not for that translation. The whole result then is, that the system begins to move about an axis, which axis begins to undergo a translation in space.

Fig. 3.



For higher theoretical investigations in this subject, the reader is referred to the writings of M. Poinsot. The best practical view will be derived from experiments with the GYROSCOPE. See also an article on the Gyroscope by Mr. John Bridge in the 'Philosophical Magazine' for November, 1857.

ROTATION OF CROPS. It has been observed in a former article [ARABLE LAND] that a repetition of the same crops in succession has a peculiar effect on the soil, so that if grain of the same nature be sown year after year in the same ground, it will not produce the same return of the seed, even when abundantly manured. The reason of this is not satisfactorily explained, but the experiments which have been made by men of science lead us to conclude that the real cause will be gradually discovered; and considerable advances have been made towards a rational solution of the question. It has been observed that it is the formation of the seed which principally causes the deterioration of the soil; for if the crop be fed off in a green state, or mown before the seed is formed, the same may be safely repeated, and no diminution of the plants is apparent. Thus grasses in a meadow which are mown before the blossom is faded or the seed formed, will spring up again vigorously; but if the seed be allowed to ripen, the roots die away, and the best grasses gradually disappear. It is thus that when a meadow is mown year after year for hay, and the earliest grasses are allowed to ripen their seed, the crop will be later and later, and all the earliest grasses will disappear. Irrigation prevents this, and seems to restore to the land whatever the grasses require for their continuance. Feeding off the meadows does the same; and this leads to the conclusion that water restores the power of production; and that the grasses not being permitted to run to seed, the deteriorating effect is not produced.

If it had been a mere exhaustion of the nutritious particles in the soil which caused the deterioration of the subsequent crops, some kind of manure might restore the fertility; but this is not the case. However judiciously the land may be manured, it is not practicable to raise a crop of wheat or clover, or of many other plants, on a soil which has shown that, as the farmers say, it is *tired* of that crop; but clover grows well after wheat, and wheat after clover, so that the same effect is not produced in the soil by these two crops. A plant which has fibrous roots, and throws up a seed-stem with few leaves, thrives best after one which has a fleshy root and many succulent leaves on a branching stem. Thus, wheat and oats thrive after beans or clover; barley and oats after turnips, carrots, or potatoes. Independently of the manure which may be put into the ground, the crops will be better where the proper succession is attended to, than where plants of a similar kind are made to follow each other.

In all countries where peculiar attention has been paid to agriculture, the most advantageous succession of crops is generally known; and if any deviation takes place, it is as an exception to the rule, and is not looked upon as a model for imitation, but rather as an experiment of a doubtful result. Certain general principles are commonly admitted as fully established; the chief of these is, that a plant with a naked stem and farinaceous seed should follow one with a branching stem and a fleshy root, which has been taken from the ground by mowing or feeding before the seed was ripe; or if all these conditions cannot be obtained, that some of them at least should be complied with. Wheat sown after clover, which is allowed to be the best succession on light soils, fulfils all the conditions: when it is sown after beans, the condition of the preceding crop not ripening its seed is given up; and consequently this succession is inferior to the other, but it is admirably effective nevertheless on all heavy soils. Potatoes, at first sight, appear to fulfil all the necessary conditions; but although they do not often ripen the seed above ground, in the formation of the tubers the soil is notoriously deteriorated.

In order to find the crops which may advantageously succeed each other in rotation, many circumstances must be taken into consideration. First of all the quality of the soil, and its fitness for particular crops; next the wants of the farmer and his family, and the maintenance of the stock required to produce a sufficient supply of manure. It is unreasonable to expect poor light land to produce wheat and beans, although by high cultivation these crops may be forced. Rye, oats, and roots may give the farmer a better profit, by being raised at a less expense than more valuable crops, which must be forced with manure, and at best are precarious in soils not adapted to their growth. In moderate loams wheat may recur every fourth or fifth year, whereas in very rich compact loams it may recur every third, and even every alternate year. Clover and many artificial grasses do not succeed well if they recur oftener than every sixth year, or with even a longer interval. Rape, flax, and potatoes require a still more distant recurrence on the same ground. All these considerations lead the farmer to the selection of the most advantageous rotation for the soil of his farm; and where the land in a considerable district is nearly of an uniform quality experience soon establishes a course which no one finds it prudent to deviate from. It happens frequently however that a great variety of soils, very different in their nature and fertility, are intermixed; and then, unless the farmer can apply the true principles of rotations, he may greatly err by following the course, which may be very judicious for the prevailing soil of the district, but not at all suited to some of his fields. Hence a knowledge of the crops suited to any particular soil, and the order in which these crops should succeed each other, is indispensable to the advantageous cultivation of a farm.

That which forms the food of man is always the principal object in the cultivation; and, excepting rice, which only grows in warm climates, there is no food more universally used than that which is made from wheat. Rye, barley, oats, and pulse are only substitutes where wheat cannot be raised in sufficient quantities. Next to grain comes meat, chiefly beef, mutton, and pork, of which the consumption increases with the wealth of a nation and the advance of its agriculture. Wheat and fat cattle are therefore primary objects with every good farmer; and he who can raise most wheat and fatten most oxen or sheep or pigs will realise the greatest profit.

Many circumstances may indicate a deviation from the course which, as a general rule, is most advantageous. The facility of purchasing manure from neighbouring towns may allow of more frequent crops of corn, and of nutritious roots which require much manure, such as potatoes, and which give no return to the land in the shape of dung. But we must lay down rules for those who are to rely on their own resources to recruit the land with manure, so that it may give the greatest produce without diminishing in fertility; and this can only be done by a judicious feeding of livestock.

The simple rotation of wheat and beans alternately would be by far the most profitable in rich clay soil, as both these crops always obtain a good price in the market; but if a whole farm were so cropped, nearly all the manure must be purchased; for, after a few crops, the wheat-straw and bean-halm would not produce half the manure required for the land. Hay and oats must be purchased for the horses required for the tillage, which might not be procured so readily or so cheap as they may be raised on the farm. On very light sands wheat or beans cannot be raised, except by a very expensive mode of cultivation; but rye, oats, peas, buckwheat, and roots for cattle must be substituted. On chalky loams the principal crops are barley and artificial grasses for sheep. In short, no particular rotation can be prescribed without a complete knowledge of the soil, the locality, and every circumstance connected with any particular farm. As the most universal rule, it may be laid down that every alternate crop should be consumed by animals on the farm, and that, as much as possible, the plants which succeed each other should be of different natural botanic families. Experience has generally shown the time that should be allowed to intervene between the recurrence of the same kind of crop, and we have only to form our plans accordingly.

Of the old triennial course (fallow, wheat, barley or oats) it must be observed that the two corn-crops so rapidly deteriorate the soil, that a complete year of fallow is required to purify it, and a good manuring to keep the land in heart, and that all the industry of the farmer cannot keep up the fertility of the land without extraneous help, either from the manure made in towns, or in the farm-yard by cattle bred and kept in commons or pasture-grounds. This system, which prevailed so long, cannot be called a rotation; and no real improvement was introduced into agriculture until the notion of its perfection was exploded, and tenants were permitted to deviate from it. The rotations adopted in the place of this old system necessarily partook at first of its main defects. Green crops were introduced of necessity to supply the loss of the commons and pastures, which, as the population increased, were gradually cultivated as arable land: but the two white crops remained in succession, and even now, such is the force of habit and early impression, that one of the most difficult points to be gained with practical farmers, accustomed to the old rotations, is to make them have patience when their land is in a good state, and to prevent their sowing a white crop, which is immediately profitable, instead of a green crop, which will keep the land in heart and improve it for future crops, but which does not figure in the account of sales. Yet it can be clearly shown, that in most cases the second corn crop is dearly purchased by the expense required to restore the land to the state in which it was when the seed was sown a second time: manure alone will not do this; fallowing and repeated ploughing can alone effect it: and whether you plough several times before a crop, or are forced to do so after it, there is no difference in the expense of labour, although there may be much in the value of the subsequent crops.

The Norfolk course (turnips, barley, clover, wheat), which is so well known and deservedly in repute for light sands, has only one defect, which is the too frequent recurrence of clover. Rye grass, the usual substitute in sandy soils, unless it be fed off young, is far inferior to clover as a preparation for wheat, and this accords with theory; for wheat and rye grass are both of the natural family of the *gramineæ*. Tares or vetches are a good substitute in heavy soils, as well as beans, both of which are *leguminosæ*, but not well suited to light sandy soils. Peas are sometimes introduced; but they are apt to encourage weeds, unless the crop be very heavy, and then they exhaust the soil, and leave little vegetable matter behind them in their roots.

In many countries there are other vegetable products, which are required for the food of the inhabitants, or supply the raw materials of manufactures: these must be introduced into the rotations, according to their effect on the soil and the cultivation they require. Indian corn, or maize, and French beans, for their seed, are cultivated in more southern climates as field crops. Potatoes are now an essential product in some districts, and one which, after maize, produces the greatest quantity of food for man from a given portion of land. But potatoes require much manure, and cannot profitably be cultivated to a very great extent as a farm produce, nor repeated on the same land, for any length of time, oftener than once in eight or ten years; they should however always enter into the rotation in that portion of the land which is to be much worked, cleaned, and manured after a crop of corn.

We have ourselves for many years adopted a rotation without being tied down to any positive rule, which has been suggested by circumstances, and in some measure regulated by our conviction of the truth of the theory we have attempted to elucidate. In a clayey loam on an impervious subsoil, but mostly completely drained, we have had turnips and swedes on high ridges, tares, mangel-wurzel, potatoes, and a portion of rye to cut up green; succeeded by barley and oats sown with clover, rye-grass, and other biennial grass seeds. These were mown for hay the first year, and sometimes the second also, but generally depastured one year at least; then followed beans, and after these wheat. The green crops were put in after repeated and deep tillage, and with an ample allowance of manure. The whole of the layer was top-dressed with peat or coal ashes in the first year, and what manure could be got or spared was put on the second year before winter, when it was ploughed up. All the corn crops were put in upon one shallow ploughing. We have had no reason ro repent of pursuing this course: but we allow that one year only in clover would probably be more profitable. The land is not sufficiently fertile by nature to bear wheat after the first year of clover, instead of feeding or making it into hay. This would bring it to some of the rotations adopted in rich alluvial soils. It is a rule which should never be transgressed, that after every crop reaped there should be a remnant of manure sufficient to ensure a good crop the next year; and that this should always be in the land, and considered as stock in trade or capital invested at good interest. By means of judicious rotations and thus a much greater quantity of produce may be raised at a certain expense of labour and capital, than by any desultory and experimental mode of cropping. The farmer should find it his own interest to cultivate his land according to the most approved principles, and the landlord should impose only such restriction as will prevent the tenant from injuring himself by diminishing the produce of his farm.

It is in the relation of crops to manure—to the need of it for them, and the supply of it through them, that the practical man sees the advantage of rotations. There is a need of rotations arising out of our relations to our labourers who want constant employment—to our live stock, which need constant food—to the soil, which will not continue to produce the same plant perpetually—to the plants we cultivate, which grow more luxuriantly in rotation than in constant succession. And the explanation of this last fact has been founded on the ideas that (1) crops poison the land for themselves; (2) that they exhaust the land for themselves; (3) that they improve the ground for their successors. Turnips for instance consumed on the land bring on it more nitrogenous matter than was given them in their manure; and so the land is enriched by this practice and rendered fit for grain, which on the other hand uses more nitrogenous matter than it can in general naturally obtain.

The following are our common rotations—

1.	2.	3.	4.	5.
1. Wheat.	1. Wheat.	1. Wheat.	1. Wheat.	1. Wheat.
2. Turnips.	2. Turnips.	2. Turnips.	2. Turnips.	2. Turnips.
3. Barley.	3. Barley.	3. Wheat.	3. Barley.	3. Barley.
4. Clover.	4. Grass.	4. Barley.	4. { Clover. Beans.	4. Clover.
	5. Grass.	5. Clover.		5. Oats.
				6. { Potatoes. Beans.

6.	7.	8.	9.
1. Wheat	1. Wheat.	1. Wheat.	1. Wheat.
2. Turnips.	2. Beans.	2. Rye followed by turnips.	2. Oats.
3. Potatoes.	3. Wheat.	3. Barley.	3. Turnips.
4. Wheat.	4. Clover.	4. Clover.	4. Barley.
5. Clover.	5. Wheat.	5. Oats or wheat.	5. Clover.
6. Oats.	6. Swedes.	6. { Beans. Turnips.	
7. Beans.	7. Wheat.		
	8. Mangold.		

10.	11.	12.	13.
1. Wheat.	1. Fallow.	1. Fallow.	1. Fallow.
2. Rape.	2. Wheat.	2. Wheat.	2. Wheat.
3. Oats.	3. Clover.	3. Barley.	3. Beans.
4. Wheat.	4. Oats.	4. Clover.	4. Wheat.
5. Clover.	5. Beans.	5. Oats.	5. Mangold.
6. Wheat.	6. Barley or wheat.	6. Beans.	6. Barley.
7. Beans.		7. Wheat.	7. Clover.
			8. Wheat.

1, is the Norfolk rotation—2, the North of England modification of it—3, Mr. Thomas's, of Lidlington, modification of it—4, a common modification of it in Norfolk—5, the East Lothian 6-field rotation—6, a common modification of it—7, the Whitfield 8-field course—8, Hewitt Davis's light land rotation—9, the rotation of the Cotteswold district, Gloucestershire—10, common in the fens of Lincolnshire—11, in clay-lands, East Lothian—12, carse-lands of Scotland—13, clay-lands of Essex. These rotations vary greatly in their manure producing power. By some one cwt. of meat may be made per acre—by others not a quarter of a cwt.—By some therefore there is food per acre for an ox, making 20 tons of dung for every 4 acres, and on others hardly one for every 16 acres.

ROTATORY OR CIRCULAR POLARIZATION. [POLARIZATION.]

ROTE, a musical instrument of former times, mentioned by the early French writers of romance, and by Chaucer, as well as others among our early poets: it seems to have been similar to what the French call a *vielle*, and the English a hurdy-gurdy.

ROTTENSTONE. [EMERY; *Tripoli Powder*.]

ROTUNDA, a term applied to buildings which are circular in their plan both externally and internally, or else to halls and other apartments of that shape, included within and forming merely a portion of the edifice containing them. The technical application of the term is however restricted to circular buildings whose height does not much exceed their diameter, for we should not describe a lofty cylindrical edifice, such as a round tower, by the term rotunda; while on the contrary it is frequently employed to designate polygonal buildings which approach in their general form to the circle.

In ecclesiastical architecture circular and polygonal structures were by no means uncommon among the early Christians, especially for baptisteries and sepulchral chapels. The tomb of Theodoric, or what is now called Santa Maria Rotunda, at Ravenna, is a singular example, having a flattish or segmental dome (about 34 feet in diameter) cut out of a single block of stone. Of San Stefano Rotundo and Santa Costanza mention has been made under ROMAN ARCHITECTURE, and to them may be here added the Rotunda or Church of Santa Maria Maggiore at Nocera, a work of about the same period. While it greatly resembles Santa Costanza in plan, having coupled columns placed on the radiating lines from the centre, and with arches springing from them, it differs altogether in section from both those examples, there being no cylindrical wall or tambour above the colonnade, but the dome springs immediately from the columns, and the arches groining into it. Consequently the proportions are much lower, the diameter of the space enclosed by the columns being 39 feet, and the height to the top of the dome 42,—proportions differing very little from those of the Pantheon. The extreme internal diameter is 78 feet. The earlier edifices of this class are, for the most part, of moderate dimensions, but others were afterwards erected on a larger scale, and among them is the celebrated baptistery at Pisa [BAPTISTERY], which is externally about 120 feet in diameter, and 100 in height, exclusive of the dome. Circular churches, or baptisteries, are also of frequent occurrence in Germany and France; and in England are three or four round churches of semi-Norman (12th century) character which are supposed to have been designed in imitation of the Church of the Holy Sepulchre at Jerusalem: such are the round churches at Cambridge and Northampton, and the Temple Church, London.

The rotunda became afterwards in a manner incorporated with or added to the cruciform plan, being raised aloft and placed over that part of it where the transepts intersect the body of the edifice. Nearly all modern cupolas may be described as rotundas elevated above the rest of the building and viewed by looking up into them from below. Thus supposing there was a floor at the level of the whispering gallery at St. Paul's, the dome and space beneath it would form a perfect and well proportioned rotunda, whose height and diameter would very nearly be the same.

In itself alone the rotunda form does not accommodate itself to the purposes of a church: it does not afford space for the processions and occasional ceremonies required by the Roman Catholic worship; nor is it better fitted for the Protestant service from its requiring an amphitheatrical arrangement of seats in concentric curves. Rotundas are accordingly rare even in Roman Catholic churches, yet although such structures are necessarily limited by their form to a moderate size, they derive from it also a grandeur which would not be produced by the same scale according to any other plan. Neither grandeur nor beauty however results as matter of course from the plan alone, because whatever charm that possesses may be nullified by other circumstances. There is, for instance, nothing of the one and not very much more of the other in the rotunda interior of St. Peter-le-Poor's, London, one of the few instances we are acquainted with of such plan being adopted for a Protestant Church. The arrangement of the pews and seats in parallel rows, strikes as a disagreeable contradiction to the shape of the building; and in this case the vaulted dome, which is almost essential to such plan, is wanting, a cove and lantern with windows being substituted for it. Some few dissenting chapels have been built of a circular form, but they are equally unsatisfactory, whether regarded as architectural objects, or for congregational purposes.

Instead of attempting to describe these and other examples of rotundas, we shall put our notices relative to them into a condensed form, and for convenience sake shall include those already mentioned, as their relative sizes can thereby be more readily compared.

Pantheon, Rome. External diameter 188 feet, internal 142, internal height 142. [ROMAN ARCHITECTURE.]

Temple of Minerva Medica. External diameter 110 feet. Interior a decagon 78 feet in diameter and 105 high.

Santa Costanza, Rome. Extreme internal diameter 140 feet; diameter of rotunda within the peristyle and beneath dome 70; height of dome 130.

Nocera, Santa Maria. Extreme internal diameter 78 feet, diameter of dome and peristyle 39, height 42.

Rotunda, Forum Caracalla. Exterior diameter about 100 feet. Corinthian portico hexastyle, triprostyle. Interior diameter 80 feet, height of order 48, entire height 90.

Rotunda at S. Pietro in Montorio, Rome. (Bramante.) Exterior enclosed by a Doric peristyle of 16 columns. Internal diameter 22 feet, height 48. This edifice is generally admired as a classical piece of architecture, but it has many striking defects, and the balustrade (without pedestals) over the peristyle is intolerable.

Madonna di Campagna, Verona. (Sanmicheli.) Exterior 74 feet in diameter, nearly surrounded by a low Doric peristyle of 28 columns, making the entire diameter below 118 feet. Interior an octagon 64 feet in diameter and 101 high.

Capella Pelligrini, Verona. (Sanmicheli.) Elegant in plan, but enormously disproportioned in section. External diameter 40 feet, internal 30. Two orders within. Height to spring of dome 46 feet, entire height 64.

La Maddelina, Venice. (Temanza.) Internal diameter 55½ feet, height to spring of dome 36, entire height 63, or 7½ more than diameter. Arrangement hexagonal, that is, six arched compartments.

Halle des Blés, Paris. (De Mezières.) External diameter 228 feet, interior diameter of the rotunda beneath the dome 127, height to spring of dome 42½, to summit 105.

Possagno. (Canova.) External diameter 116 feet; width of portico 90, projection of portico 55, height of stylobate 10½, internal diameter 90, height 90.

Madre di Iddio, Turin. (Buonsignore.) A rotunda about 130 feet in diameter, with hexastyle, diprostyle, Corinthian portico. Internal diameter 74 feet, height 100; plan four semicircular tribunes, with two Corinthian columns in front of each, bearing the entablature continued over those spaces. Attic with a long panel over each of the four recesses.

Museum of the Vatican, Rotunda. (Simonetti.) Divided into ten recessed compartments: diameter 50 feet.

Radcliffe Library, Oxford. (Gibbs.) Basement a polygon of 16 sides, and 104 feet in diameter. Extreme exterior height 140 feet, interior diameter 88, interior diameter of central space and dome 52, height 90.

Berlin Museum, Central Hall. (Schinkel.) Diameter 67 feet, height of gallery supported by a peristyle of twenty Corinthian columns, around the lower part 21; height to spring of dome 42 feet, entire height 70.

Catholic Church, Darmstadt. (Moller.) Extreme internal diameter 135 feet, peristyle of twenty-eight Corinthian columns supporting dome; diameter of dome and peristyle 102 feet, height to spring of dome 48 feet, to summit 102.

Reading Room, British Museum. (S. Smirke.) Diameter 140 feet; height 106 feet. [BRITISH MUSEUM.]

ROUGE. [METALS. *Iron, peroxide of iron.*]

ROUND (*rotundus*, from *rota*, a wheel) is a term which is indiscriminately applied in common language to everything which has no very sharp corners. A cylinder and a sphere, a wheel and a ball, are equally styled *round*. In geometry, the sphere, cylinder, and cone, are sometimes denominated the "three round bodies," and it would certainly add much to many persons' power of describing shapes if they would learn the meaning of the terms circular, cylindrical, conical, spherical, spheroidal, and annular, for all of which the term *round* is employed without any distinction.

ROUND, a short vocal composition in three or more parts, in the performance of which the first voice begins alone, singing to the end of the first part, then passes on to the second, and afterward to the third, &c., the other voices following successively the same routine, till all are joined together, the round ending at the mark of a pause (𝄐) or at a signal agreed on. This is frequently, but most erroneously, called a *catch*, and sometimes, not less incorrectly, a "Canon in the unison."

ROUND TOWER. Numerous lofty towers, tapering from the base to a conical cap or roof, which crowns the summit, are found in Ireland, and are almost peculiar to that country. That they are of great antiquity appears from their having been considered ancient even in the 12th century, when the British connection with Ireland began. Had they been then in actual use, it is not probable that so accurate a writer as Giraldus Cambrensis, who had been in Ireland, and circumstantially describes them, should not also have mentioned to what purpose they were applied. Dr. Petrie, 'Ecclesiastical Architecture of Ireland,' however, quotes several records between the years 948 and 1170, in which bell towers are referred to, which he seems to be able to identify, in some instances at least, with the existing round-towers.

There are 117 of these towers, or of the sites where they once stood, now known, and there is reason to believe they were formerly more numerous. Some of them are still perfect, and preserve their conical roofs; but only one, the tower of Devenish, possesses the singular ornament of an obtuse crescent rising from the cone, and somewhat resembling what is called the trident of Seeva.

Ardmore tower, near Waterford, had also, within the memory of man, this finishing ornament. In the other towers, the conical caps are either more or less injured, or have altogether vanished. Some few are topped by battlements, but these are all of more modern construction than the towers.

Though most of these round towers were evidently divided into stories, yet Cashel tower is smooth, and even polished on the inside from top to bottom. That at Ardmore was plastered with a very fine and durable cement. The divisions are usually formed by projecting ledges for the flooring joists, which however in some instances were inserted in square holes in the wall, where the ends were still visible not many years ago.

On each floor there is one very small window, and immediately below the conical cap four windows may be traced in the greater number of towers; in one there are five and in a few six windows; and so many as eight appear in one or two of the towers. In a few of these buildings no windows appear in the upper story—only one small loophole. In most of the towers the doors are at a considerable height above the ground, in one even twenty-four feet, in several fourteen, and in others only eight, seven, or six feet, but in none of them are there any traces to assist conjecture as to the mode of reaching those doors, except in those where the door is on the ground, or raised from it by a couple of steps.

The height of these towers varies greatly, one being only thirty-five feet, while the loftiest is one hundred and thirty, but the common range is between eighty and a hundred feet. Some stand on circular bases, which form one or two deep steps round the tower. Thus Donoughmore has a two-step base, each step or plinth being composed of very large blocks of stone. The basement of Kell's tower is square, and the stones are of great size. Killree and Aghaviller, both in the county of Kilkenny, have circular plinths fourteen inches deep, projecting six inches and resting upon a square base formed of great blocks of stone. The tower of Clondalkin, about five miles from Dublin, stands on massive stone-work; and St. Columb's tower, at Londonderry, rises from a vaulted crypt. So also does that at Oughterard, in the county of Kilkenny.

In external character all the towers may be said to agree, since there is only one which does not taper, and in that case the tower is cylindrical throughout its entire height. It is nicely faced, inside and out, with coggle-stones, and filled up with rubble. Though all bear to each other the strongest family likeness, there are many striking differences in the mason-work and in the minor details. The stones in some are truly chiselled, and closely and beautifully laid in fine cement. Some are only coarsely hammered, others merely faced, and of various shapes and sizes, but still well fitted to each other. Some towers are built of round coggle-stones. In all the mortar is as hard as the imbedded stones.

The above and various other little diversities prove that these remarkable structures were erected by various workmen and at very different times, and, as Giraldus Cambrensis says, "according to the manner of the country." Some excellent Irish archæologists imagine that they range in date from the 5th or 6th to the 10th or 12th century.

Their situation on hill or dale is equally variable, nor does any one circumstance respecting their situations seem to be common to all, except their immediate vicinity to a small and very ancient church, though in some instances this ancient building has been replaced by a more modern fabric.

It is a well known fact that the early missionaries usually chose the sites of Pagan places of worship for their churches, and the undoubted relics of Pagan places of worship still remain in close association with these towers, and even in the same churchyard; the pillar stone of witness, the tapering sun-stone, the crombac, the fire-house, and the holy spring of sacred water necessary in the mystic rites, all these, according to some Irish archæologists, are found along with the tower, and the little ancient church, within the same narrow boundary.

The speculations of antiquaries as to the objects of rearing these, mysterious towers have indeed been manifold—penitentiaries, the abode of anchorites, beacon-towers, alarm-posts, places of safety for goods, sepulchral stelæ, bell-towers, trumpet-towers, from whence, by means of the great brazen trumpet, the people were invited to worship, fire-towers, where the sacred fires of Bel or Baal, who was undoubtedly worshipped in Ireland and Scotland, were kept alive, the tower itself being an emblem of the sun-beam or ray of heavenly fire, or finally that they were Buddhic in their origin, and sepulchral in their immediate application, they having been erected over the bones or relics of saints. It now seems to be the opinion of the best authorities that they are the work of Christian architects, and were built for ecclesiastical purposes. They appear to have always stood in proximity to a church or monastery, and in fact to have been employed both for bell-towers and as keeps, or strongholds, into which the ecclesiastics might retreat with the church plate and records, in case of an attack. Their origin, or the type from which they were in the first instance imitated, is however still matter of conjecture.

Before closing this article, it should be mentioned that though these towers are almost peculiar to Ireland, there are two in Scotland, but in that district which, in the very early ages, was in close and constant connection with Ireland.

In other parts of the world, as Andalusia, the Caucasus, Persia, and part of India, towers of all sizes and shapes, and in various situations, have been discovered. As in all these there are some points of resemblance, they may all perhaps prove to be successive links of that long chain of evidence by which these remarkable buildings may even yet be traced downwards from their origin to the pagan rites of the Scoti or Irish.

ROUNDHEADS, a name given to the republicans in England, at the end of the reign of Charles I. and during the Commonwealth. The name seems to have been first applied to the Puritans because they wore their hair cut close, but to have been afterwards extended to the whole republican party. The Cavaliers, or royal party, wore their hair in long ringlets. [CAVALIER.]

ROUT. [RIOT.]

ROYAL ACADEMY OF ARTS IN LONDON. At the accession of George III., painting, sculpture, and architecture, notwithstanding there were eminent artists in all these branches, were in a lower state in Great Britain than in most parts of Europe. Foreign critics did not hesitate to assert, that the ungenial climate or the physical defects of the English presented insuperable obstacles to the attainment of excellence in the arts. Whether these opinions induced the young king to turn his attention to the subject, and endeavour to remove this national stigma, cannot now be known, but it is certain that he soon began to show a strong disposition to encourage the arts.

This avowed disposition of the king encouraged the artists of the metropolis to endeavour to establish an academy of art somewhat similar to that which had long been in successful operation in France. A private academy or association of painters had been formed as early as 1711, under the presidency of Sir Godfrey Kneller; but differences arose between the foreign artists (then an important and comparatively numerous body in London) and the English members, when the latter, with Sir James Thornhill at their head, seceded and opened in 1724 a new academy. On the death of Thornhill, ten years later, his son-in-law proposed to the old society to reunite, and the two bodies formed the well-known "Academy in St. Martin's Lane." All these were, however, rather schools for drawing from the living model and the antique, and promoting mutual intercourse among the artists, than academies on the continental model: that is, in which instruction should be given in painting, sculpture, and architecture, and certain marks of distinction be conferred on the most successful professors of those arts. Several projects had, however, been put forward for the foundation of a royal academy: among others one by Sir James Thornhill, prior to the establishment of the private one above mentioned; one by Gwynn, the architect, in 1749; one in 1753 by the members of the St. Martin's Lane Academy, which probably fell to the ground through the opposition of Hogarth; and another, of which the proposals were issued in 1755. The next effort was more successful. An institution which had been formed in 1754, called "A Society for the Encouragement of Arts, Manufactures, and Commerce in Great Britain," was the first which included among its objects the offering of rewards to the fine arts. In 1760, with the assistance of the above-mentioned Society, who liberally allowed the use of their great room for the purpose, the artists were enabled to open the first public exhibition, which though not entirely satisfactory to the promoters, attracted great attention, and was for several seasons successfully followed by a similar display of their talents at a large room of their own in Spring Gardens. The associated artists were in consequence induced to apply to the king for a charter, which they readily obtained, and in 1765 they were constituted a body corporate under the title of "The Incorporated Society of Artists." The way was thus paved for the institution of the Royal Academy; but its immediate cause was a schism which took place in the "Society" soon after their incorporation. It arose from the claim set up by the directors to fill up all vacancies in their own body; this the members refused to allow, and the directors seceded. They were all men of position and influence, and they at once determined to establish a new and more restricted institution on the model of the French Academy, if they could obtain the protection and patronage of the king. W. Chambers, F. Cotes, G. M. Moser, and B. West presented to him a memorial signed by twenty-two artists, the purport of which was to show the probability that with his royal sanction and encouragement, and by means of an annual exhibition of their works, they would soon be able to raise sufficient funds for the support of a gratuitous national school of art. The memorial stated, "The two principal objects which we have in view are the establishing a well-regulated school or academy of design, and an annual exhibition open to all artists of distinguished merit; we apprehending that the profits arising from the last of these institutions will fully answer all the expenses of the first; we even flatter ourselves that they will be more than necessary for that purpose, and that we shall be enabled annually to distribute somewhat in useful charities." The proposal was graciously received. The plan of a constitution was drawn up by Mr. Chambers, and laid before the king, which he approved, and signed on the 10th of December, 1768. Thus was founded "The Royal Academy of Arts in London, for the purpose of cultivating and improving the arts of painting, sculpture, and architecture."

The artists who signed this memorial were: Benjamin West, Francesco Zuccarelli, Nathaniel Dance, Richard Wilson, George Michael Moser, Samuel Wale, J. Baptist Cipriani, Jeremiah Meyer, Angelica Kauffman, Charles Cotton, Francesco Bartolozzi, Francis Cotes, Edward Penny, George Barrett, Paul Sandby, Richard Yeo, Mary Moser, Agostino Carlini, William Chambers, Joseph Wilton, Francis Milner Newton, Francis Hayman. These, with John Baker, Mason Chamberlin, John Gwynn, Thomas Gainsborough, Dominick Serres, Peter Toms, Nathaniel Hone, Joshua Reynolds, John Richards, Thomas Sandby, George Dance, Francis Hayman, William Hoare of Bath, and Johan Zoffani, composed the original thirty-six academicians. The number forty was not completed till 1780—by the addition of Edward Burch, Richard Cosway, Joseph Nollekens, and James Barry. Their first meeting was held on the 14th of December, when the following officers were elected, namely: J. Reynolds, *President*; G. M. Moser, *Keeper*; F. M. Newton, *Secretary*; E. Penny, *Professor of Painting*; T. Sandby, *Professor of Architecture*; J. Wall, *Professor of Perspective*: Dr. William Hunter, *Professor of Anatomy*. The king appointed William Chambers *Treasurer*, and R. Wilson *Librarian*.

The other academies of Europe which have been established for the advancement of the fine arts and the promotion of public taste, are supported entirely at the expense of their respective governments as *national* objects, and are usually under the control of some person of distinction. Such is the Royal Academy of Paris, founded just a century before. The Royal Academy of London is essentially different from these, inasmuch as it originated in the private munificence of the reigning king, and, since the first years of its existence, has been entirely maintained by the proceeds of the annual exhibition.

The king's adoption of the artists was immediately followed by the most liberal and effective support. He caused apartments for the schools to be fitted up in his own palace of Somerset House, supplied the Society with rooms in Pall Mall for their exhibitions, and for several years made up every deficiency in their expenditure from his privy purse; at the same time he allowed them to reserve 100*l.* a-year to form a fund for necessitous members or their widows, and twice that sum to administer occasional relief to artists in distress, whether they were members of the Society or not. When Old Somerset House was purchased by the nation as a site for a number of public offices, the king took care to reserve a portion of the new building for the Academy. In 1766 the plans of a new site were submitted to the approval of the president and council, and the apartments devoted to this purpose were fitted up with a degree of magnificence worthy of a royal palace, the talents of many of the principal members having been employed in their decoration. In July, 1780, the preparations being completed, the Royal Academy obtained possession of their new residence, by an order from the Treasury to the surveyor-general of the works, and their first exhibition in Somerset House took place in the following year. This friendly superintendence of its affairs and anxious desire to promote the welfare and utility of the Society continued till the unfortunate illness of the king; and a like patronage has been vouchsafed by his successors.

In 1834, a proposal having been made by Lord Grey and the existing ministry to transfer the establishment from Somerset House to Trafalgar Square, where an edifice was proposed to be raised which would be also large enough for a national gallery of paintings, the sanction of the king (William IV.) was obtained, and the necessary arrangements were made with the president and council of the Academy. The apartments, which comprise the whole of the east wing of the National Gallery, were put into their possession in 1836; and they are still occupied by the Academy, though formal notice has been more than once given by the government of their intention to resume possession of them, in order to appropriate them to the use of the National Gallery.

The Royal Academy consists of forty academicians, painters, sculptors, and architects. There is a second order of members, styled associates, twenty in number, from whom alone the vacancies that occur among the academicians are supplied. The body of academicians elect, but the approbation and signature of Her Majesty are necessary to make this election valid.

There are also six associate engravers, who are classed—two as "academician engravers," two as "associate engravers of the new class," and two as "associate engravers." Associates are elected by the body of academicians, from a list of exhibitors who declare themselves candidates for this honour.

There are a treasurer, a librarian, a keeper, and a secretary. A bye-law of the Academy requires that they shall be academicians. These offices are filled by Her Majesty's nomination.

There are four professors, academicians, elected by the general assembly, and approved by the queen, who read lectures on painting, sculpture, architecture, and perspective.

There is also a professor of anatomy, elected by the academicians, with the approbation of Her Majesty.

There are three schools: a school for study from casts from celebrated works of antiquity; a school for study from living models; and a painting school. The first is under the care and direction of the keeper; and the other two are under the care of visitors, annually appointed.

The council consists of nine members, including the president, and has the management of all the concerns of the Society. All bye-laws of the Academy must originate in the council, and have the approbation of the general assembly, and the sanction of Her Majesty's signature to give them effect. The president, council, and visitors are annually elected, and confirmed by Her Majesty's signature.

There are also several honorary members of the Royal Academy, namely, a professor of ancient literature, a professor of ancient history, a chaplain of high rank in the church, an antiquary, and a secretary for foreign correspondence; these, who are always persons of eminence in literature, are elected by the general assembly and approved by the queen.

All persons are admissible as students of the Academy. Nothing but indication of talent and a respectable character are required from them. Their names remain unknown till judgment is passed on the specimens which they send in, and when admitted they receive a gratuitous education from the best masters. All painters, sculptors, or architects, whose works show sufficient merit, are allowed to exhibit with the Academy, and, being admitted exhibitors, they are immediately eligible as associates.

The executive government of the Academy passes in rotation to all the academicians, and half the council retires, and is renewed annually.

The schools of drawing, painting, and modelling are open daily from ten to three and from six to eight, under the direction of the keeper and visitors. A practical course of lectures on perspective is given during the spring. The lectures on anatomy are delivered before the Christmas recess; those on painting, sculpture, and architecture are given twice a week, from January to the end of March. The library is open three times a week.

Prizes are annually given to encourage meritorious students, and those who have gained the biennial gold medal have from time to time an opportunity of being sent abroad to study for three years at the expense of the Academy.

The library of the Academy contains all the best works on art, besides a considerable number of modern prints and a valuable collection of engravings of the Italian school from the earliest period, formed by George Cumberland, for which they paid 600*l*. On the death of Sir Thomas Lawrence, the Academy purchased his collection of architectural casts for 250*l*. (although their apartments could not accommodate them): they are at present deposited in the South Kensington Museum.

Considerably over two thousand students have been reared under the tuition and auspices of the Royal Academy, and among them are included by far the greater number of those who have distinguished themselves as painters and sculptors in this country.

The attention which the Royal Academy has uniformly shown to unfortunate artists in general, and the liberal assistance they have bestowed to such out of their funds, should not be omitted. It appeared in evidence before a committee of the House of Commons, in 1836, that the gross sum which they had expended in pensions to distressed members amounted to 11,106*l*., and the donations to artists, not members, and their families, to 19,249*l*.; and since then, with increased funds, the Academy has acted with still greater liberality. With this generosity the Academy has combined a prudent degree of economy in the management of its funds, both for the purpose of providing against casualties and for the gradual improvement of the establishment. Notwithstanding the large sum they have expended in carrying out the objects for which they were associated, the academicians have accumulated a reserve fund sufficient, as they informed the Chancellor of the Exchequer when the question was mooted of the removal of the Academy to Burlington House, to erect a new building more adequate to their requirements than their present apartments, provided the government would furnish the necessary site.

It will appear from what has been stated, that the Royal Academy owes its corporate existence entirely to the crown, and is neither supported nor aided by any public funds. It has also been shown in what manner it became entitled to accommodation in the National Gallery. Though the exertions of the Academy have been directed to a public object—the improvement of the arts—it differs in no respect from any other body incorporated for literary or scientific purposes, such as the Astronomical Society for instance, and others, which support themselves by their own funds.

Accordingly when in the year 1834 the House of Commons had addressed the king, William IV., requesting him to direct the Royal Academy to furnish them with certain returns explanatory of the constitution of the body and its proceedings, the Academy, though protesting against the attempt to withdraw the Royal Academy from its immediate connection with the crown and to bring it under the control of the House of Commons, having first asked the permission of the king, gave the House all the information that was desired. But in 1839, when an order was made to furnish the House with similar returns in continuation, as well as with the particulars of their domestic expenditure, these returns were not made, and a petition was presented to the House, in which the position and claims of the Royal Academy were fully explained. The petition seems to have produced its effect, and the order was rescinded.

Within the last few years it has seemed on more than one occasion probable that the question of the position of the Academy, both as a private institution and with reference to the public benefit, would come under discussion in parliament, but it has been deferred. This question it does not fall within our province to consider, nor to notice the various attacks made on its constitution and administration. It is sufficient here to have stated what these are.

ROYAL SOCIETY (of London), consists of a number of persons associated together for the purpose of promoting mathematical and physical science. At its formation the more particular object of the members was to assist each other in extending their knowledge of natural and experimental philosophy.

Philosophical societies for the cultivation or advancement of particular branches of human knowledge existed, both on the Continent and in this country, before the end of the 16th century. In Italy, the Florentine Academy and the Academia della Crusca had been founded with the view of improving the language and literature of that country. France had its Academy of Painting and Sculpture, and its Royal Academy of Inscriptions; and the Antiquarian Society in England was founded in 1572.

England appears to have led the way to the formation of a body of men who sought by mutual co-operation to advance the *new philosophy*, as it was called; for Dr. Wallis, in an account of his own life, relates that in 1645, which must therefore have been while the civil war was raging in the country, several persons who then resided in London, at the suggestion of a Mr. Haak, a native of Germany, joined themselves into a club, in which, purposely excluding politics and theology, they agreed to communicate to each other the results of their researches in chemistry, medicine, geometry, astronomy, mechanics, magnetism, navigation, and experimental philosophy in general. Among those who first met for this worthy purpose were Drs. Wilkins, Wallis, Goddard, Ent, and Glisson, and Messrs. Haak and Forster (the professor of astronomy at Gresham College); and the place of their meeting was generally at Dr. Goddard's lodgings, but they occasionally assembled in Gresham College or in its neighbourhood. This is supposed to be the club which Mr. Boyle, in a letter (1646), designates the invisible or philosophical society.

Before the year 1651, Drs. Wilkins, Wallis, and Goddard, having obtained appointments at Oxford, went to reside in that city, where, being joined by Drs. Seth Ward, Bathurst, Petty, and Willis (the last an eminent physician), and Mr. Rooke, they constituted themselves a society similar to that which they had left in London. They met at first at Dr. Petty's lodgings, which were in the house of an apothecary, where they had access to such drugs as they wished to examine; and as often as any of the members had occasion to visit the metropolis, they did not fail to attend the meetings of their former associates. When Dr. Petty went to Ireland in 1652, the meetings at Oxford appear to have been for a time suspended; for that gentleman, writing from Dublin to Mr. Boyle, in the beginning of 1658, expresses his gratification that the club was revived; and in the same year the members met either at the apartments of Dr. Wilkins, in Wadham College, or at the lodgings of Mr. Boyle: the Oxford society continued to exist till 1690, when the meetings terminated. It appears, however, that, in the beginning of 1659, all of them, except Mr. Boyle, who continued to reside at Oxford till 1668, came to London, where they rejoined the friends who had remained there, and where the united clubs were almost immediately strengthened by the accession of several new members. At that time the lectures on astronomy and geometry in Gresham College were delivered, the former by Mr. Christopher Wren, on every Wednesday, and the latter by Mr. Rooke (who had been appointed in 1652), on every Thursday; and these gentlemen, together with Viscount Brouncker, Mr. Brereton (afterwards Lord Brereton), Sir Paul Neile, Mr. John Evelyn, Mr. Ball, Dr. Croone, and others, besides the Oxford members, used after the lectures to assemble for philosophical conversation in an adjoining room. This state of things did not, however, continue long, for during the same year, in consequence of the troubles which ensued on the resignation of the Protectorship by Richard Cromwell, the apartments which had been occupied for scientific purposes were converted into quarters for soldiers, and the members of the society were obliged to disperse.

We learn also from Dr. Wallis that, upon the restoration in 1660, the meetings were revived; and on the 28th of November, in that year, the members came to a resolution that they would assemble during term time in Mr. Rooke's chambers at Gresham College, and during the vacation at Mr. Ball's chambers in the Temple. It was further resolved that the members should constitute themselves a society for promoting physico-mathematical learning, similar to the voluntary associations of men for other branches of knowledge in foreign countries. At this time also a series of resolutions relating to the objects proposed by the society was drawn up, of which the following is a brief outline:—It was agreed that records should be made of all the works of nature and art of which any account could be obtained; so that the present age and posterity might be able to mark the errors which have been strengthened by long prescription, to restore truths which have long been neglected, and to extend the uses of those already known; thus making the way easier to those which are yet unknown. It was also resolved to admit men of different religions, professions, and nations, in order that the knowledge of nature might be freed from the prejudices of sects, and from a bias in favour of any particular branch of learning, and that all mankind might as much as possible be engaged in the pursuit of philosophy, which it was proposed to reform, not by laws and ceremonies, but by practice and example. It was further resolved that the society should not be a school where some might teach and others be taught, but rather a sort of laboratory where all persons might operate independently of one another. Lastly, it was resolved that each member should subscribe his name to an agreement that he would constantly attend the society's meetings, if not prevented by illness or some indispensable business; that he should pay 10*s.* on his admission, and that he should subscribe 1*s.* weekly while he continued to belong to the society; but from this obligation he was to be freed if he chose to withdraw. At the same time Dr. Wilkins was chosen chairman, Mr. Ball, treasurer, and Mr. Croone, registrar. It was agreed to meet every Wednesday, from 3 to 6 o'clock in the afternoon.

The revenue thus raised from the members was intended to enable the society to accomplish the various objects for which it was instituted, and particularly to defray the expenses of the philosophical experiments which it was proposed to make. The intention was, that persons should be sent to travel abroad, for the purpose of collecting information, while others should remain in London, and present the results of their researches at the weekly meetings. It was determined that the members should be formed into committees for the consideration of the subjects which were to be illustrated by experiments, and that the performance of the latter should be assigned to persons who, by their particular talents, were best qualified for the duty. Some of the members also were to be appointed to examine all works on the natural history of foreign countries, that out of them they might prepare directions as a guide in making inquiries concerning the phenomena of the atmosphere and the currents of the sea, and in performing experiments on light, magnetism, &c. It was proposed to bring the results of the researches into one common stock, and to consign them in public registers for the benefit of future generations, without regard to any order in the arrangement; it being considered, that if subjects of a like nature were brought together, persons might be tempted too early to form general systems, which might be detrimental to the progress of philosophy. (Dr. Sprat, 'History of the Royal Society.')

Such were the plan and constitution of the infant society, which was destined, in its maturity, to hold so distinguished a place in the annals of science. Its first recorded steps, which took place Dec. 5, 1660, consisted in appointing Mr. Wren, at the next weekly meeting, to perform an experiment on the vibrations of pendulums, and Lord Brouncker to bring in a series of instructions for conducting some experiments (relating to the temperature, moisture, &c., of the air), the performance of which on the Peak of Teneriffe it was intended to procure.

A week afterwards it was resolved that persons desiring to be admitted should be recommended by some member, and that the election should take place by ballot. No one below the rank of a baron was to be admitted without a scrutiny; and the number of members was to be limited to fifty-five, of whom twenty-one were to be a quorum for elections and nine for other matters. It was agreed also that the fellows of the Royal College of Physicians and the professors of mathematics and natural philosophy in both universities should, if they desired, be admitted as supernumeraries on paying the fees and lending their assistance when convenient. The restriction respecting the number of members was however soon afterwards taken off; and, at this time, candidates who were proposed on one evening were often admitted at the next, or at the second following meeting, though the practice respecting the interval between the application and the admission seems to have been very variable. The president or chairman held his post sometimes during the evening only, sometimes he was appointed for a month, and he was occasionally re-elected. Two persons were appointed to superintend the arrangements for performing the proposed experiments, and one of the members acted as a reporter at the meetings. An amanuensis for copying minutes, and an operator under the superintendents, were engaged as servants, and received salaries.

In that age, the constitution and qualities of material bodies being very imperfectly known, suggestions founded on ill-observed phenomena, and the marvellous relations of credulous travellers, were often thought deserving of consideration from the bare possibility that they might lead to the discovery of useful truths; and this circumstance may serve to account for the apparently absurd inquiries and experiments which appear in the notices of the society's first labours. Thus, in 1661, Mr. Boyle was requested to ascertain the name of the place in Brazil where there was said to have been a kind of wood which attracts fishes; he was also desired to inquire into the truth of the circumstance mentioned by Schotter—that a fish suspended by a thread would turn towards the wind. And in the same year, the opinion that a spider could not get out of a space enclosed within a circle formed of powdered unicorn's horn was actually made the subject of an experiment. The philosopher will however forget these early occupations of the society when he meditates on the works of a Newton and a Davy, which are also recorded in the pages of its history.

The society having presented an address to the king (Charles II.) on his restoration, his majesty expressed much satisfaction that the institution had originated in his reign, and promised to support it with his influence. And in 1662, by the concurrence, it is said, of Lord Clarendon, the chancellor, Sir Geoffry Palmer, the attorney-general, and Sir Heneage Finch, the solicitor-general, he granted a charter, by which the members were incorporated into a society consisting of a president, council, and fellows, under the name of the Royal Society. In this they were declared capable of holding lands, tenements, &c. in perpetuity or otherwise, and of suing or defending in any court of law; a coat of arms was given them, and they were allowed to have a common seal for their use. William Viscount Brouncker was appointed president, and twenty-one persons were appointed by name to form a council. It was further regulated that the president should be elected annually on St. Andrew's day, and that ten of the council should, at the same time, be replaced by ten other persons chosen from among the fellows. (Birch, 'History of the Royal Society,' vol. i.; Weld, 'Hist. of Royal Soc.' vol. i.) This charter being found not sufficiently explicit, in the following year another was obtained, in which the president and fellows are designated the president of the council and the fellows of the Royal Society of London for promoting natural knowledge; and in which, after declaring that the society might hold lands, &c., there is added "Statuto *de alienatione in manum mortuam* non obstante." (Birch, *ut sup.*) Between 1661 and 1664, the king made several visits to the society, and on those occasions experiments were exhibited, for the preparation of which committees of the members were appointed. In 1663 his majesty bestowed a mace on the society, and in 1664 he signed himself, in the Charter-book, its founder; at the same time the duke of York (afterwards James II.) signed himself a fellow.

The Royal Society of London may now be said to have been completely formed, and it must be considered as the oldest of its kind in Europe, if we except the Academy of the Lyncei at Rome. The Académie Française, which, in 1635, had been established by Richelieu, had for its object only the improvement of the French language; and though, in 1657, a number of learned men, among whom were Descartes, Gassendi, and Roberval, were accustomed to assemble at the apartments of Père Mersenne in Paris, for the purpose of making philosophical experiments, and of reading the solutions of such mathematical problems as, according to the general practice of that age, had been proposed to them, yet it was not till 1666 that Louis XIV., at the suggestion of M. Colbert, founded what was then called the Royal Academy of Sciences for purposes similar to those which engaged the attention of the Royal Society. To the latter therefore belongs the honour of having preceded the former in time, and probably that of having in some measure led to its formation. It must also be considered as having been the parent of the numerous scientific institutions which have since been formed in the British Isles as well as on the continent.

From the time of the charter being granted, the business of the society assumed more importance, and in 1664 Mr. Hooke was appointed curator, with a salary of 80*l.* per annum. The west gallery of Gresham College was appointed as a repository for the instruments which were under his charge, and for a museum of natural curiosities which had been given by Mr. Colwal, one of the members. Sir John Cutler also settled on Mr. Hooke 50*l.* per annum, in consideration of his delivering a course of lectures on the History of Nature and Art, under the regulation of the society; and the latter, in the same year, formed itself into seven committees for the purpose of considering the different subjects of which it was cognizant. These were mechanics, astronomy and optics, anatomy, chemistry, agriculture, the history of trade, natural phenomena; and there was, besides, a committee to manage the correspondence. The Royal Society early received many tokens of approbation from foreign nations, as well as from the nobility and the learned in this country. It corresponded frequently with the scientific men in France, and it was invited by Prince Leopold, the brother of the grand-duke of Tuscany, to keep up a mutual communication with the philosophers of Florence. The Germans published in their books favourable testimonials of its labours, and foreigners of distinction often attended its weekly meetings.

The first portion, or number, of the 'Philosophical Transactions,' as the work which the society published was designated, appeared on Monday, March 6, 1665. It contained sixteen quarto pages, with an introduction by the secretary of the society, Mr. Oldenburg, who was considered as the editor; and it was intended that one such number should be published on the first Monday of every month. After the fifth number came out (June, 1665), the public meetings of the members were discontinued on account of the plague which then raged; but it appears from a letter written by Mr. Boyle, at Oxford, to Oldenburg, who remained in London, that several of the members were then in the former city, and that they met and made experiments at his lodgings. From these experiments and the communications made by some of the members, there were formed three more numbers of the 'Transactions;' these were published at Oxford; but the ninth and all the succeeding numbers came out in London. The title of the work was changed in 1679 to that of 'Philosophical Collections,' when Dr. Hooke became the editor; but the former title was restored in January, 1683, with No. 143, which was published by Dr. Plot, who was then the secretary.

The council met again in Gresham College, in February, 1666, but the public meetings of the society did not take place till June in that year. In the same year the great fire, which laid nearly all London in ashes, having compelled the authorities of the city to take possession of the rooms hitherto occupied by the society, the latter gratefully accepted the offer of apartments in Arundel House, and it met there for the first time in January, 1667. The munificent owner of the mansion, Mr. Henry Howard of Norfolk (afterwards earl marshal of England), at the same time presented the society with the library which had been purchased by his grandfather, Thomas, earl of Arundel, and which had formerly belonged to Matthew Corvinus, king of Hungary. This valuable library, consisting of several thousand printed volumes and numerous manuscripts, thus became the property of the society, which immediately took measures to put it under the care of its own officers, and it has been subsequently greatly increased by donations and purchases. Being probably anxious to trespass as little as possible on the hospitality of the noble family to whom the mansion belonged, the society proposed (November, 1667) to raise, by subscription among its members, money to build a college for itself; and by May in the following year 1000*l.* were subscribed. Mr. Howard at the same time generously promised to give the ground for the purpose. The same gentleman also offered a design for the building, and both Dr. Christopher Wren and Mr. Hooke gave plans; but it does not appear that the project was carried any further. In October, 1674, at the invitation of the Gresham professors, the society returned to its former apartments in that college, which had now the name of the Royal Exchange. The west gallery was cleared out for the society as a repository, and the long gallery as a library for the reception of the books, which had till then remained at Arundel House.

Soon after this time the prosperity of the society seems to have suffered some diminution. In 1667, when Dr. Sprat's 'History' was published, there were nearly 200 members; in 1673, it appears that the number was only 146, and of these 79 were persons who had long neglected to pay their subscriptions. This great number of defaulters gave much uneasiness to those who wished well to the society; and the latter, besides making pressing applications for the arrears, seriously contemplated an attempt to enforce payment by legal processes. It does not appear that this last measure was ever put in practice, and the council adopted a more effectual means of promoting the welfare of the society in charging themselves with the duty of delivering lectures on philosophical subjects, and in providing a number of good experiments. The first lecture, in pursuance of this plan, appears to have been delivered in 1674, by Sir William Petty, and it was ordered to be printed. The president (Lord Brouncker) also proposed, in 1668, that a silver medal, worth about twenty shillings, should be given to any fellow, not a curator, who should make before the society any particularly meritorious experiment.

Dame Lady Sadleir, the relict of Dr. Croone, one of the earliest members, left by her will, in 1706, a sum of money for the purpose of founding a lecture *for the advancement of natural knowledge*, to be read before the Royal Society; this did not however come into operation till 1738, when the first was delivered by Dr. Stuart. The Bakerian lecture on electro-chemistry was founded in 1774, and the first was delivered in 1775, by Mr. Peter Woulfe.

In the infancy of the society a due attention to the characters of the persons admitted as fellows does not appear to have been always given; and, in consequence, many joined who neither paid the fees nor contributed any information at the meetings, and, at the same time, the number of those who were excused the payments was found to bear too great a proportion to the whole. In order to remedy these evils, in 1682, the president, Sir Christopher Wren, brought in the draught of a statute in which it was provided that any person proposing a candidate for admission should give his name to some member of the council; at the next or at some following meeting of the council, it was to be considered whether the proposed candidate was likely to be useful to the society or not; if the members were satisfied on this head, the candidate was to be formally proposed at the next meeting, and afterwards balloted for as usual. On his election he was to sign the statute book, and on or before being admitted, he was to pay the prescribed fees. In the same year it was agreed that none except foreigners should be exempted from the payments. It is to be presumed that the persons who were excused the payment of the admission fees or the weekly subscriptions were such as, from the pressure of their circumstances, were unable to incur the expense, or such as, from the services which they rendered to the society, might justly claim the exemption: among those who petitioned to be excused on the former ground is to be found the name of Newton, then resident at Cambridge.

It was proposed, in October, 1674, to refuse to strangers the permission, which had been before granted, to be present at the meetings of the society, from an opinion that members might be unwilling to bring forward their communications in the presence of such persons. And at the same time it was proposed that the members should bind themselves not to divulge what passed in their meetings, it being thought prejudicial to the interests of the society that the particulars of the experiments and communications should be made known before they appeared in the printed 'Transactions.' We read that, on one occasion only, a lady was permitted to be present at the meetings of the society; this was in 1667, when the Duchess of Newcastle, having expressed a wish to that effect, it was agreed to invite her grace, and some experiments, which had been prepared for the purpose, were repeated in her presence.

By the death of Dr. Wilkins (then bishop of Chester), one of the earliest members, the society obtained a legacy of 400*l.*, which, in January, 1675, was laid out in the purchase of an annual income of 24*l.* from certain fee farm rents at Lewes, in Sussex; and in January, 1682, the college and lands in Chelsea, which had been granted to the society, were sold to the king for 1300*l.*; this sum was soon afterwards vested in African and East Indian stock, and from that time the society began to possess a permanent revenue. Till the year 1668 no fixed salary was allowed to the secretary; but Mr. Oldenburg, who had long held that post, received 50*l.* occasionally, and in that year it was agreed to allow him 40*l.* per annum. After his death (1677) two secretaries were appointed, with salaries; but in 1685, Mr. Aston and Mr. Robinson declining on a sudden to serve the society, the council resolved, in order to avoid the inconvenience of being so deserted in future, to have two honorary secretaries; it was agreed also to have a secretary with a fixed salary to transact the business, and the qualifications required in the person who should fill the latter post are stated at length in Birch's 'History,' vol. iv. Of the former, Sir John Hoskyns and Dr. Gale were the two first; and in January, 1686, Mr. Edmund Halley was appointed the paid secretary, at 50*l.* per annum.

In 1701, the society, which till this time had continued to hold its meetings in Gresham College, removed to a spacious house which it purchased in Crane Court, Fleet Street. This house afforded room for the meetings, for the library, and for the museum of curiosities; and here the reading of papers and the exhibition of experiments took place, as before, till the year 1782, when the government assigned to the society apartments in Somerset House. On removing to the latter place, it became necessary to dispose of the museum for want of room; but this inconvenience was obviated in 1826, when the rooms formerly used by the commissioners of the lottery were given up to the society. The rooms in Somerset House were resumed by the government in 1857, other and more commodious apartments being granted in their stead in Burlington House, Piccadilly.

In 1703 Sir Isaac Newton was appointed president of the society, and this honourable post was held by the greatest of philosophers till his death, which happened in 1727. The experiments of Newton on telescopes and on light and colours were amongst the first subjects which gave a value to the 'Transactions' of the society; and the latter showed its sense of the honour which it derived from being able to number him among its fellows, by publishing in 1686, the first edition of the 'Principia.' [PRINCIPIA.]

The service rendered to the cause of science from the beginning of the 18th century has earned for the society the respect and gratitude of every man to whom the advancement of the human intellect is an object of high consideration. The society numbers among those who are and who have been its members some of the brightest ornaments of philosophy and human nature; and it may be said that a large proportion of the discoveries by which the face of science has been changed have been made known to the world through the papers published in the volumes of its 'Transactions.'

It has been said above that the 'Philosophical Transactions' were at first published in monthly numbers: these were afterwards collected into volumes, and, from the commencement in 1665 to the year 1800, the work consisted of 90 volumes. From that time a volume has come out annually, and, up to the present year (1861), 150 volumes have been published. It appears that, till the 47th volume was published, the printing of the 'Transactions' was entirely the act of the several secretaries, the society never interesting itself further in that matter than by occasionally recommending the revival of the publication, when from any circumstance it appeared to be suspended. But in 1752 a committee was appointed to consider the papers which were read before the society, and to select such as should be judged most proper to appear in the future 'Transactions,' and this practice has ever since been followed. The society, however, constantly declares that it never, as a body, gives its opinion on any subject, whether of nature or art, which comes before it, the facts and reasonings stated in their papers resting entirely on the credit and judgment of their respective authors.

Honorary recompenses have been liberally bestowed by the society on persons distinguished by their discoveries in pure science or in philosophy. The first occasion on which the society became possessed of the means of so rewarding merit arose from a bequest of Sir Godfrey Copley, one of its members; this gentleman, at his death in 1709, left 100*l.*, the interest of which, or 5*l.*, was to be given annually to the person who, in the course of the preceding year, had written the best paper on any subject relating to experimental philosophy. The donation has since been put in the more liberal form of a gold medal, and it is awarded indifferently either to foreigners or Englishmen, for the sake of encouraging an honourable competition among the philosophers of all countries.

In 1796, Sir Benjamin Thomson (Count Rumford) presented to the society 1000*l.* in the 3 per cent. stock, for the purpose of forming, with the interest for two years (60*l.*), a biennial prize to be given for the most important discovery, or the most useful improvement, made during the two preceding years on heat or on light. The prize is given in the form of a gold and a silver medal, both of which are struck in the same die. During several of the biennial periods no opportunity occurred of awarding the prize, and at these times the interest was added to the principal sum. The interest of this additional sum is always given with the two medals; and the first who received the prize was Count Rumford himself, in 1800, and the second was Professor Leslie (1804). In 1825 his Majesty George IV., for the purpose of further promoting the objects and progress of science, made to the society an annual grant of 100 guineas in order to establish two prize medals, which are to be presented to the persons who during the year shall make the most important discovery in science or art; and in 1826 the medals were awarded to Mr. John Dalton and Mr. James Ivory.

On delivering to a gentleman the medal which had been awarded to him for his discoveries in science, Sir John Pringle, who held the office of president from 1772 to 1778, made it a rule to deliver a speech, in which, after touching on the history of that branch of philosophy to which the discovery or communication referred, he stated the particular points in which the individual had distinguished himself. The first of these speeches was made on presenting to Dr. Priestley the gold medal for his paper entitled 'Observations on the Different Kinds of Air,' which had been read before the society in March, 1772. This liberal practice, by which the value of the testimonial to the receiver is so much enhanced, is still continued; and it is also become customary, at every anniversary meeting, to notice, in an appropriate speech, the principal circumstances in the life of any distinguished member who may have died during the year.

It is perhaps impossible that, in a large body of men engaged in similar pursuits, differences should not arise; and the Royal Society has not been entirely free from the evils attending disagreements among its members. It will be enough to refer to the dispute about the comparative advantages of blunt and pointed conductors for protecting buildings from the effects of lightning, which in 1778 arose to such a height that the president, Sir John Pringle, felt himself compelled to resign [Pringle, John, in Biog. Div.]; and to the accusations at a later period against Sir Joseph Banks of partiality in the disposal of the medals and even in the election of members. In the first instance, the president may have erred in putting himself at the head of a party in the society; but it is probable that most of the grievances subsequently complained of originated mainly in the disappointed expectations of ambitious individuals. If at any time, however, the complaints have not been without foundation, the elevated character of the papers which for many years have been published in the 'Transactions' shows that the interests of science have been generously placed above every private consideration.

According to the present statutes of the society, every candidate for admission must be recommended by a certificate in writing signed by six or more fellows, of whom three at least must certify that the recommendation is from personal knowledge; and the name, qualifications, &c., of the candidate must be entered in a book kept for the purpose. At the first ordinary meeting in March of each year a list of the names of all candidates proposed subsequently to March 1 of the preceding year, is suspended in the meeting-room till the day of election; and a printed list is forwarded to every fellow of the society. From this list the council select by ballot fifteen names to be recommended to the society for election. The election takes place on the first Thursday in June, when the person elected must appear for admission on or before the fourth ordinary meeting of the society after his election; and previously to such appearance he must pay the sum of 10*l.* for admission money; he must also pay 4*l.* per annum as long as he continues a fellow of the society; but the annual payments may be compounded for by paying at once the sum of 60*l.* Fellows are entitled gratis to a copy of the 'Philosophical Transactions,' commencing with that volume which is published next after their admission. Any fellow disobeying the statutes or orders of the society or council, or defaming the society by speaking, writing, or printing, or doing anything detrimental or dishonourable to the society, will be ejected from it.

A prince of the blood, a peer of the United Kingdom, a member of the privy council, any foreign sovereign prince, or the son of such prince, may be proposed at one of the ordinary meetings of the society and voted for on the same day, notice having been given of such proposal at the preceding meeting of the society. Foreign members are exempted from the obligations which ordinary fellows are enjoined to perform; but their number is not to exceed fifty.

The council and officers for the ensuing year are elected on the 30th of November; the latter consist of the president, treasurer, principal secretaries, and foreign secretary. The new council consists of eleven members of the existing council and of ten fellows who are not so. These are nominated previously to the anniversary meeting.

The ordinary meetings of the society are held once a week, from the third Thursday in November till the third Thursday in June, at half-past 8 P.M., in the apartments at Burlington House.

ROYALTY. The French words *roi* and *royal* correspond to the Latin words *rex* and *regalis;* and from *royal* has been formed *royalté* (now *royauté*); whence has been borrowed the English word *royalty.* The corresponding Latin word is *regalitas,* which occurs in the Latin of the middle ages. (Ducange, *in v.*)

Royalty properly denotes the condition or *status* of a person of royal rank, such as a king or queen, or reigning prince or duke, or any of their kindred. [King.] The possession of the royal *status* or condition does not indicate that the possessor of it is invested with any determinate political powers; and therefore *royalty* is not equivalent to *monarchy* or *sovereignty.* The powers possessed by persons of royal dignity have been very different in different times and places; and have varied from the performance of some merely honorary functions to the exercise of the entire sovereignty. The *kings* (ἄνακτες, βασιλῆες) of the Homeric age were properly a governing class of nobles. (See Müller, 'Hist. of Liter. of Greece,' ch. iv, § 1.) Thus Telemachus says that there are many kings in Ithaca, both old and young, besides himself ('Od.', i. 394); and Alcinous says that he rules over the Phæacians, with twelve other kings ('Od.,' viii. 390). As popular institutions were developed in Greece, the office of king became, in several states, merely honorary, and was particularly connected with the performance of certain ancient religious rites. Thus at Athens, the king-archon (ἄρχων βασιλεὺς) was an annual officer, who had the superintendence of religious affairs; his wife was called, during the year of office, βασίλισσα, or *queen.* (Compare Hermann, 'Gr. Ant.,' § 56.) Rome likewise retained, after the expulsion of its kings, a high sacerdotal officer, named the *king of the sacrifices* (rex sacrificulus), who performed the sacred rites which had formerly been performed by the kings. In like manner the Teutonic kings were only the chiefs of the military and sacerdotal aristocracy of the tribe, and did not possess the entire sovereign power ("nec regibus infinita ac libera potestas,") says Tacitus, 'Germ.,' 7. [King.]

In popular discourse *royalty* is made equivalent to *monarchy* or *sovereignty;* and a king is called monarch or sovereign without any reference to the fact whether he possesses the entire sovereign power or only a portion of it.

It may be added, that the attribute of royalty is sometimes transferred metaphorically to certain animals or species of animals, in order to denote pre-eminence. Thus the principal bee in the hive is called the queen-bee; the lion is known (particularly in fables) as the king of animals; and a species of tiger is styled the *royal tiger.* Compare Sovereignty.

Royalty is also used to describe certain rights in property. Thus on the working of mines of gold and silver in the United Kingdom, the sovereign is entitled to a royalty, as is also the Prince of Wales, as Duke of Cornwall, on the working of tin mines. The term is likewise applied to the sum paid for the use of a patent or a copyright.

RUBEFACIENTS are external agents which cause redness of the part to which they are applied. If long continued, they may, according to their nature, produce inflammation and some of its consequences. In such circumstances they are termed Blisters, or Escharotics. It is however a degree of action short of what entitles them to these appellations which is now contemplated. Thus friction with the hand or warm cloths often relieves spasmodic or neuralgic pains; and a hot poultice or warm fomentations lessen inflammation of superficial or even deep-seated parts. Embrocations, when of a stimulating kind, act as rubefacients; and blisters kept in contact with the surface for a short time only, cause redness of the part, and some remote secondary effects of a very beneficial kind. Many cases of fever in the sinking stage may be recovered by a succession of flying blisters, as these temporary applications are termed, placed on different parts of the body, particularly over parts where the skin is thin. Their action may be expedited by previously rubbing the part with proof spirit or oil of turpentine, or by using a portion of linen steeped in the acetum cantharidis instead of the common blister. By diligent employment of such means many valuable lives may be saved. Rubefacients are also very usefully applied to the spine in many nervous, and some cutaneous diseases.

RUBEOLA is the name given by Sauvages, in 1768, to the disease known as measles [Measles]. He was followed by Willan, Bateman, and other writers on exanthematous diseases. Previous to the time of Sauvages the measles was called *morbilli,* a name which is at present adopted by many medical writers. The term rubeola has been recently applied by Dr. Copland and other writers, to a disease which has been called by Hildebrand and other German writers Rötheln. This disease possesses characters in common with measles and scarlet fever, and is supposed to be a hybrid disease originating in the poisons of these two diseases. However much such a theory may be open to criticism, there seems to be no doubt in the minds of many writers that the disease is very frequent, and that it is confounded with its two parent diseases. The following definition of this disease is given by Dr. Aitken, in his 'Science and Practice of Medicine.' "A specific eruptive disease preceded by and accompanied with fever, watery discharges from the eyes and nose, sneezing, and sore throat. The eruption appears on the third or fourth day, and consists of crimson stigmata, rapidly running together into patches of an irregular shape, with obtuse angles, and of sizes varying from a threepenny to a crown piece, according to the severity of the case. The eruption continues from six to ten days, and terminates in desquamation by furfuraceous scales."

The distinction between this disease and scarlet fever and measles has been pointed out by Dr. Paterson of Edinburgh, and by Dr. Heim of Berlin. The premonitory fever is longer than in scarlet fever, and about the same time as measles; scarlet fever appearing on the second day, rubeola and morbilli on the third or fourth. The rash is more easily confounded with scarlatina than morbilli. It seldom however is of a uniform red as in the first, and the spots are larger than in measles. The eruption in scarlatina and measles remains but three days, whilst in rubeola it remains from five to ten days. The sore throat is a marked symptom of rubeola in its mildest forms, whilst this symptom is very slight in mild cases of scarlatina, and altogether absent in measles. Dropsy is a frequent attendant on scarlatina, but very rare in rubeola, whilst affections of the lungs are common in measles but not in rubeola.

Like scarlet fever it is sometimes a rapidly fatal disorder. The treatment of this disease must be similar to that of scarlet fever. In mild cases little needs to be done. [Scarlatina; Measles.]

RUBERYTHRIC ACID. [Madder, Colouring Matters of.]

RUBIACIC ACID. [Madder, Colouring Matters of.]

RUBIACIN. [Madder, Colouring Matters of.]

RUBIADIPIN. A resinous substance contained in madder root.

RUBIAFIN. [Madder, Colouring Matters of.]

RUBIAN. [Madder, Colouring Matters of.]

RUBIANIN. [Madder, Colouring Matters of.]

RUBICHLORIC ACID. [Madder, Colouring Matters of.]

RUBINDINIC ACID. [Indigo.]

RUBINIC ACID. [Tannic Acids.]

RUBIRETIN. [Madder, Colouring Matters of.]

RUBITANNIC ACID. [Tannic Acids.]

RUBLE. [Money.]

RUBRIC (from the Latin *ruber*, red), a name given to the titles of chapters in certain ancient law-books; and more especially to the rules and directions laid down in our Liturgy for regulating the order of the service. These, in both instances, were formerly written or printed, as the case might be, for distinction's sake, in red characters, and have retained the name though now printed in black.

RUDDER. [Ship.]

RUDOLPHINE TABLES. [Kepler, in Biog. Div.]

RUE (*Ruta graveolens*), a plant, native of the south of Europe, intermediate between a herb and a shrub, of a peculiar yellowish-green colour. Every part of it is marked by transparent dots, filled with volatile oil. The leaves and immature fruits are officinal, and owe their virtue to the volatile oil and a bitter extractive. The odour is peculiar, strong, and penetrating; the taste intensely bitter, aromatic, and stimulating. One hundred parts of the fresh herb dry into twenty-two parts. The quantity of oil obtained by distillation with water varies much according to the period of growth when it is collected. Thirty pounds of the fresh herb before flowering scarcely yield one drachm, while twelve pounds with the fruits almost ripe yield nearly one ounce. Rue possesses powerful, stimulant, anti-spasmodic, and tonic properties. The careless handling of the fresh plant sometimes causes rubefaction and vesication, and its improper employment internally has produced serious results. When judiciously used, it is very serviceable in hysteria and other convulsive disorders; but its incautious administration by nurses to infants should be guarded against.

Oil of rue obtained from the fresh herb is green, from the dried herb yellow. It has the peculiar odour of rue, and a bitterish, acrid, cardamum-like taste. Its specific gravity is 0·911. It does not redden litmus-paper. The oil met with in commerce is rarely genuine, being an artificial compound of oil of turpentine with petroleum and oil of rue.

The pollen of the flowers produces inflammation of the skin, and any of it received into the eyes causes violent lachrymation and other painful effects.

Rue is frequently cultivated as an ornamental plant, for which its curiously cut leaves, their glaucous hue, and the profusion of fine dark yellow flowers appearing for several months in succession, adapt it exceedingly well. It may be increased by seeds, slips, or cuttings. The seed should be sown in March, and when the young plants are two or three inches high they should be put out in nursery rows; but propagating by slips or cuttings is best, especially for continuing varieties, of which there are three or four.

RUFIGALLIC ACID. [Gallic Acid.]

RUFIN. [Phlorizin.]

RUFINIORIC ACID. [Tannic Acids.]

RULE OF THREE. [Three, Rule of.]

RULE (in Law) is an order of one of the three superior courts of Common Law. Rules are either general or particular.

General rules are such orders relating to matters of practice as are laid down and promulgated by the court for the general guidance of the suitors; the power of issuing rules for regulating its practice being considered incident to the jurisdiction of the court. By recent acts of Parliament, the judges are authorised to make rules of a more comprehensive nature, relating as well to pleading as to practice. Formerly each court issued its own general rules, without much consideration as to what was the practice in other courts. Of late the object has been to assimilate the practice in all the courts of common law.

Rules not general are such as are confined to the particular case in reference to which they have been granted. Of these, some, which are said to be "of course," are drawn up by the proper officers on the authority of the mere signature of counsel, without any formal application to the court; or in some instances—as upon a judge's fiat or allowance by the master, &c.—without any signature by counsel; others require to be handed in as well as signed by counsel. Rules which are not of course are grantable on the application, or, as it is technically termed, "the motion," either of the party actually interested or of his counsel. Where the grounds of the motion are required to be particularised, the facts necessary to support it must be stated in an affidavit by competent witnesses. After the motion is heard, the court either grants or refuses the rule. A rule, when granted, may, according to the circumstances, be either "to show cause," or it may be "absolute in the first instance." The term "rule to show cause," also called a "rule nisi," means that unless the party against whom it has been obtained shows sufficient cause to the contrary, the rule, which is yet conditional, will become absolute. After a rule nisi has been obtained, it is drawn up in form by the proper officer, and served by the party obtaining it upon the party against whom it has been obtained, and notice is given him to appear in court on a certain day and show cause against it. He may do this either by showing that the facts already disclosed do not justify the granting of the application, or he may contradict those facts by further affidavits. The counsel who obtained the rule is then heard in reply. If the court think proper to grant the application, or if no one appears to oppose it, the rule is said to be made "absolute." If they refuse the application, the rule is said to be "discharged."

Rules may be moved for either in reference to any matter already pending before the court, as for a change of venue in an action already commenced, or for a new trial, &c.; or in respect of matters not pending before the court, as for a criminal information, a mandamus, &c.

A copy of a rule obtained from the proper officer is legal proof of the existence of such a rule.

RULE, RULER. In a mechanical sense these words are both used for a straight piece of wood, brass, or ivory, from which a straight line is drawn on paper by guiding a pen or pencil along the edge. These rules or rulers are convenient for the laying down of scales, on which point see Scale; Sector; Sliding-Rule.

The word rule, in its more common sense, means a set of directions for the attainment of any required object, and various rules will be found in this work, scattered under many heads. The word rule is generally dropped; thus we do not speak of the rule of addition, or the rule of subtraction, but simply of addition or subtraction. In some isolated cases the word rule is most usually retained, as in the rule of three [Three, Rule of] and the rule of false. [False Position.]

A rule differs from an algebraical formula only in the language employed; both the former and the latter indicate processes to the mind. The rule describes its data at length, and requires many more signs than the formula, which however is much more intelligible than the rule, so soon as its symbols are well understood. For example, when it is known that a, b, c are the units in the sides of a right-angled triangle, the formula for determining c is—

$$c = \surd(a^2 + b^2):$$

the rule is—To find the hypothenuse of a right-angled triangle, multiply the number of units in each side by itself, add the products, and extract the square root of the sum: this square root is the number of units in the hypothenuse required. It might perhaps be thought that the preceding rule might have been expressed more briefly, but the practice of abbreviating the language of rules is almost sure to destroy the sort of advantage which, in one point of view, they possess over a formula. A rule should embody a description of the object to be gained, and the process by which it is to be gained; it should also point out the step at which it is gained, and everything necessary to describe the result. It should even specify the case in which the rule is to be used, or that in which it becomes necessary rather than any other; and should be so complete in itself, that any reader of that class to whom the book is addressed might learn all it teaches (that is, everything but the demonstration) by reading only what comes between the word Rule and the full stop at the end of it. Thus, though we have described the preceding rule in words which some persons may think too many, we should say that they are not too many for the student who is somewhat of a mathematician, and too few for the beginner. For the latter we should state as follows:—To find the hypothenuse of a right-angled triangle of which the two sides are given, reduce the two sides to the same denomination if necessary (feet and decimals of a foot, inches and decimals of an inch, &c., as most convenient), multiply the units in each side by itself, add the results, and extract the square root of the sum: this square root is the number of such units in the hypothenuse as were used in the expression of the sides.

If however many rules are to be learned, it would in all probability be found more easy to learn the symbols of alegbra, that is, to learn to read an algebraic expression and to use formulæ, than to recur frequently to rules.

RULER, PARALLEL. A good form of this instrument is explained under MARQUOI'S RULERS, which is particularly applicable to the case in which numerous and related parallels or perpendiculars are to be drawn. The ordinary instruments are of two kinds, which might well be called parallel *rulers* and parallel *rollers*.

The principle of the common parallel ruler is a parallelogram of constant sides and changeable angles: one side being fixed and the angles altered, the other side changes position, it and its parallels always remaining parallel to the first side and its parallels. Two rectangular rulers are connected by two cross-bars of equal lengths, which move on pivots in the rulers in such manner that the four pivots, two in each ruler, shall be the four points of a parallelogram. The line joining two pivots on the same ruler is always made parallel to the length of the ruler. One ruler being held fixed, and a line drawn with the edge of the other ruler in any position, then any motion given to the other ruler by the rotation of the cross-bars gives, on the edge of the moving ruler, a line parallel to the first line. The defects of this construction are, that the four pivots may not make an accurate parallelogram, in which case the instrument is worthless: and the sides of the two rulers, when the instrument is closed, may not be parallel to one another, in which case all the lines must always be taken off the same ruler. Moreover, one ruler remaining fixed, there is but a small command of distance from it; so that, to gain the parallel required, it may happen that the first ruler has to be advanced, the second brought up to it, the first ruler advanced again, and so on. Now, owing to the rotation of the pivots, this gives an oblique motion to the instrument; so that it often happens, by the time that the required parallel is gained, that the point through which it is to be drawn is off the ruler. To meet this disadvantage, and to give the instrument more extent, three rulers are sometimes put together, each connected with the next by cross-bars in such manner that the cross-bars connecting the first and second have an opposite revolution to those connecting the second and third. At its best however this instrument is rather clumsy; but, such as it is, it is safe and easily earnt, when well made.

The simplest kind of roller is the common round ruler, which, with a little practice, will draw parallels for ordinary use very well. It is good practice in the use of instruments to draw parallels in this way; the ruler being held in the middle and gently allowed to take its own rolling motion. If a ring be well drawn round the ruler, it is good practice in drawing perpendiculars to adjust the ruler so that the ring may roll over the line to which perpendiculars are to be drawn. But a roller which is more easily used is sold in all the shops. It consists of an ordinary ruler of rectangular form, both edges of which are bevelled and divided into equal parts: one side into inches and tenths, the other into inches and twelfths; the inch divisions being made to come exactly opposite each other. A roller is let into a space cut out of the middle of the ruler, in such manner as to project a very little way from the under and upper faces of the ruler. When the instrument is put down on the paper, either of the bevelled edges may be brought down on the paper, or both may be clear of it. In this last case the roller (the efficient ends of which are *toothed* cylinders, the middle part being in a frame) rolls easily, and additional stability is given if, while it rolls, one of the bevelled edges be kept slightly on the paper. The ends of the roller are graduated and a fixed index is in the frame, so that by allowing equal numbers of divisions to pass the index at each roll, a good approximation (though not quite with a draughtman's accuracy) may be made to equidistant parallels. Perpendiculars to a given line are drawn by adjusting the ruler so that opposite divisions of the bevelled edges may travel on the given line. With a very little practice this is an instrument of great power and accuracy. Before using it, draw a line with it, roll it away, and then roll it up again to that line, and see if the coincidence is as perfect as before. Various other modes of trial will suggest themselves: indeed no one should use a parallel ruler at all until he has drawn pairs of parallels across each other, and satisfied himself that he can get the opposite sides quite equal.

A rough construction of this kind was (perhaps is) sold under the title of 'Schlesinger's Patent,' in which a round ruler of wood is simply connected with a flat bevelled ruler, so as to carry it when it rolls. This is meant to rule lines for writing, but it may be made to do good service as a parallel ruler for other purposes.

RUM is a spirit distilled from the sugar-cane, that is, from cane-juice; or from the scummings of the juice from the boiling-house; or from treacle, or molasses; or from "dunder," the lees of former distillations. What is called *pine-apple rum* is not distilled from different substances: it is simply flavoured with slices of pine-apple put into the puncheon. As the entire juice of the cane is not necessary for making rum, the distillation is carried on in conjunction with the manufacture of sugar. The best rum is made from the uncrystallised syrup called molasses. [MOLASSES.] The proportion of molasses made in crystallising a cwt. of sugar varies from 50 to 90 gallons, and depends both upon the climate and the season; being lowest in the Leeward Islands, which have a dry climate, and highest in Demerara and Trinidad. It is in the latter that in fine seasons the proportion reaches 90 gallons per cwt. Nearly one gallon of proof rum may be made from one gallon of molasses.

The rum consumed in the United Kingdom is entirely the produce of the West Indies, and to a great extent of the island of Jamaica, which is of a superior quality. For many years the home demand has not taken off the whole supply; and the surplus, which consists chiefly of the Leeward Islands rum, and other kinds of inferior quality, is exported.

British spirits are said to be extensively sold for rum, the flavour being imitated by the rectifier.

The equalisation of the duties on East and West India sugar, by 6 Wm. IV. c. 26, rendered it expedient to give a practical equality to all the products of the sugar-cane, without which the cultivation of sugar plantations in India could not have been so profitably extended, as the molasses would have been comparatively wasted. The rum consumed in the navy is exempt from duty. That which we re-export is chiefly sent to Germany, Prussia, Holland, Italy, and Australia. After various changes in the mode of arranging the duty, it was determined in 1847 that rum should pay the same amount of Customs' duty as British spirits paid of Excise duty. There still remained a few anomalies, arising out of the excise duty being unequal in different parts of the United Kingdom; but this inequality was removed in 1858, and in 1860 the State was put in the receipt of 10*s*. 2*d*. per gallon on all rum, gin, whiskey, and British spirit of every kind, consumed in the United Kingdom; and an additional 3*d*. per gallon on rum not the production of the country whence imported.

The rum imported in four equidistant years will show the recent progress of the trade:—

1844	3,120,010	gallons.
1849	5,306,827	"
1854	8,625,907	"
1859	6,878,587	"

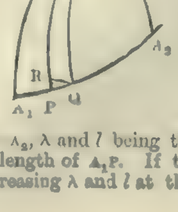
The *computed* real value in 1854 (the first year in which such values were calculated by the Customs), was 1,490,661*l*.; from which the values for the other years named may easily be calculated, supposing the price to have remained unchanged. In looking at the above numbers, it would seem as if rum had been rapidly increasing in consumption in England about the year 1854; but such was not the case. Of the whole quantity imported, only the following (in each year) was retained for *home consumption*:—

1844	2,198,592	gallons.
1849	3,039,862	"
1854	3,226,594	"
1859	3,575,679	"

The large excess beyond these quantities was either re-exported, or consumed on shipboard.

RUMB or RHUMB. Vitalis ('Lex Math.') calls this a Portuguese word, and no doubt it might have been introduced into navigation by the Portuguese, but we suspect it to be the Latin "rhombus;" he says it signified originally the meridian, or the principal meridian of a map; perhaps it came to signify this from such meridian being usually ornamented by a distinctive rhombus, such as is added to the north direction on a compass-card. However this may be, a rumb certainly came to mean any vertical circle, meridian or not, and hence any point of the compass; so that, in modern phraseology, a rumb is one of the thirty-two principal compass directions, and to sail on any rumb is to sail continually on one course. Hence a rumb-line is a line drawn in the sphere, such as would be described by a moving point which always keeps one course; it is therefore the spiral of Mercator's projection, and is that which is also called the loxodromic spiral.

The mathematical properties of the rumb-line may be easily deduced. Let r be the radius of the earth, λ_1 and l_1 the longitude and latitude of



A_1, and λ_2 and l_2 those of A_2, λ and l being those of any intermediate point P: and let s be the length of A_1P. If then we increase s by the infinitely small arc ds, increasing λ and l at the same time by $d\lambda$ and

dl, we have the differential triangle PQR, in which $\mathrm{PQ}=ds$, $\mathrm{PR}=r\,d\lambda$, $\mathrm{RQ}=r\,dl\,.\cos\lambda$, while the angle RPQ, which is the same throughout the curve, may be called ρ. We have then $ds\,.\cos\rho=r\,d\lambda$, or $s\,.\cos\rho=r(\lambda-\lambda_1)$ integrating from A_1 to P. Again, $ds\,.\sin\rho=r\,dl\,.\cos\lambda$, so that the two equations give

$$\frac{d\lambda}{\cos\lambda}=dl\cot\rho,\text{ or }\log\cot\left(\frac{\pi}{4}-\frac{\lambda}{2}\right)=l\cot\rho+\mathrm{C};$$

the logarithm being Naperian, and the angles being arcually measured. If L be the length of the arc of a degree of longitude at the equator, and if we now use degrees, and extend the preceding integration from A^1 to A_2, we have—

$$r\log\frac{\cot(45^\circ-\frac{1}{2}\lambda_2)}{\cot(45^\circ-\frac{1}{2}\lambda_1)}=(l_2-l_1)\,\mathrm{L}\cot\rho;$$

an equation from which ρ can be found for any two places, that is, the angle which the course in sailing from one place to the other makes with the meridian. And instead of $r:\mathrm{L}$ may be put its value 57·29578. The distance from one place to the other on the rumb-line sailed over may be found from $s\cos\rho=r(\lambda_2-\lambda_1)$, which, when λ_2 and λ_1 are measured in degrees, becomes $s\cos\rho=(\lambda_2-\lambda_1)\,\mathrm{L}$, neglecting the small correction for the earth's eccentricity.

The first of these processes can be done by Mercator's chart, the principle of which, mathematically described, is as follows:—Let equal arcs of longitude remain equal throughout the map, but as increments of latitude are to their corresponding increments of longitude as 1 to the cosines of the latitudes, let the differential triangle PQR be similar in the chart to that on the sphere, which gives $a\,d\lambda:\cos\lambda$, for the representation of $d\lambda$ on the chart, provided a represent the length of the degree of longitude on the chart. Hence $a\log\cot(45^\circ-\frac{1}{2}\lambda)$ is the length of λ degrees of latitude measured from the equator; and a table of values of $\log\cot(45^\circ-\frac{1}{2}\lambda)$ is called a table of *meridional parts.*

In such a chart all rumb-lines are projected into straight lines; but equal parts on any such straight line do not represent equal distances on the earth: and the distance sailed must be found by the formula in terms of the extreme latitudes and the angle of the course.

RUMICIN. [CHRYSOPHANIC ACID.]

RUNES, the letters of alphabets in use amongst the ancient Gothic or Teutonic nations of the north of Europe. The word has been derived variously from *ryn*, the Gothic for "to cut;" *rin*, or *ren*, "a furrow," or "channel," from the resemblance of the letters to those objects; *raunen*, the German for "to whisper;" and *ryne* or *rûn*, a "mystery" or "secret art." The two latter derivations are based upon the idea that the Runic characters were taught perfectly only to the priests and ministers of religion; or that they were used as lots when inscribed on small sticks or stones, which, when shaken together and drawn out, served for purposes of augury and divination.

By some writers the invention of Runes has been ascribed to Ulphilas, a Gothic bishop, who flourished about A.D. 350; but more modern investigations have shown that they were far anterior to his time. The circumstance which led to the supposition that Ulphilas had invented Runes, arose from the fact that he introduced Greek characters among the Goths. These he amalgamated with the already existing Runic letters, and formed an alphabet which is now known as the *Mœso-Gothic*, as the Latin characters introduced into England, probably by Augustine, are known as the Anglo-Saxon. Others again have attributed to the Runes a Roman origin; but Tacitus says that the Teutonic tribes possessed letters of the alphabet when the Romans first became acquainted with them, although he calls them "secreta literarum," and thus seems to intimate that the knowledge of letters and their powers was confined to certain classes only of the people. Moreover the pure Runic alphabet consists only of sixteen letters, and these have nothing in common, either in their names or order, with the Greek, the Roman, or the Gothic characters of Ulphilas. The probability is that, according to the opinion of Fr. Schlegel, the alphabet was originally introduced amongst the inhabitants of the coasts of the Baltic by the Phœnician merchants who traded there; that it was only revealed partially to the general body of the people, whilst the priests reserved the full knowledge of it to themselves, in order to establish their claim to superior power and intelligence by the exercise of magic arts and the employment of mystic signs. These signs were frequently cut upon smooth sticks, called rún-stafas, *mysterious staves*, and were used for the purpose of divination and priestcraft.

There is a legend which attributes the invention of Runes to the god Odin or Woden, and which states that he migrated from Asia about the time of the invasion of Darius Hystaspes (B.C. 508); and, having settled in Scandinavia, established temples, a priesthood (to whom he communicated the Runic letters, together with the mythology of the Edda), and became both the legislator and civiliser of the north of Europe. Others again place the migration of Odin at the period of the overthrow of Mithridates by Pompey (B.C. 66), and assert that he fled from the country of the Caucasus, settled in Upsala, and, having distributed Norway, Denmark, and Gothland amongst his sons, was worshipped as a god after his death. Notwithstanding the obscurity of these myths, they seem undoubtedly to point to the fact that the pure Runes were introduced into the North from the East, and that the opinion of Grimm, Schlegel, and those who attribute to them an Oriental origin, is more correct than that of those who suppose them to have been derived from the Greek or Roman alphabets, although there is but little doubt that they became afterwards modified by the introduction of Greek and Roman characters.

The three classes into which Runic letters and inscriptions may be divided are, 1, the Scandinavian or Norse; 2, the German; 3, the Anglo-Saxon; and of these each has its own peculiar alphabet. The origin of the first of them is, as has been already observed, involved in considerable obscurity; the second stands between the ancient Northern, or Scandinavian, and the Anglo-Saxon, and is thus considered by Grimm to have sprung from the former, and to have been the parent of the latter. The Anglo-Saxon Runes were in all probability derived from the Marcomannic or Norman runic alphabets, that is, from the characters used by the Nordalbingii, or Saxons north of the Elbe, who were the progenitors of the Anglo Saxon race. The Marcomannic Runes resemble the Anglo-Saxon, but they do not at all resemble the Norse in form; but all the three nations agreed in attributing the primary invention of Runes to Woden (the Mercury of the Anglo-Saxons), and all of them shared in the belief of the magical properties and powers appertaining to and supposed to be inherent in runic letters and inscriptions.

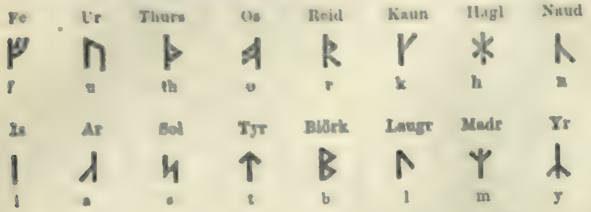
The fact that Runes were generally considered to have been the invention of a pagan deity, that they were used by pagan priests and prophetesses for purposes of augury and divination, and that these priests and prophetesses were regarded by the people with religious veneration and awe, accounts for the proscription of Runes by the primitive Christian priesthood throughout Europe. Hence the Christian missionaries laboured everywhere to introduce Greek or Latin characters, and endeavoured with the utmost zeal to suppress Runes. Notwithstanding this, however, Runic characters were used in England at the very earliest period after the introduction of Christianity, for Christian inscriptions—a circumstance that is incontrovertibly proved by those discovered at Bewcastle in Cumberland, and Hartlepool in Northumberland, and elsewhere. This has been accounted for by the supposition that the earliest converts to Christianity were the pagan priests themselves, and that they, knowing the really worthless character of Runic letters, had not the slightest objection to using them, either by themselves, or in combination with Roman or other letters, either in manuscript or for inscriptions. It is said, however, that by the year 1001 the Runic characters were quite laid aside in Sweden, and were officially condemned in Spain at the council of Toledo in 1115.

The Norse Runic alphabet consisted of sixteen letters, called respectively, *fé*, *ur*, *thurs*, *os*, *reid*, *kaun*, *hagl*, *naud*, *is*, *ar*, *sol*, *tyr*, *biörk*, *laugr*, *madr*, *yr*, and answering in sound to our letters *f*, *u*, *th*, *o*, *r*, *k*, *h*, *n*, *i*, *a*, *s*, *t*, *b*, *l*, *m*, *y*; from which it will be seen that there were no letters corresponding to our *d*, *e*, *g*, *p*, *q*, *v*, *w*, *x*, *z*. Hence the sign of *k* acted also for *g*, *d* for *t*, *b* for *p*, *u* and *y* for *v*. *O* was expressed by *au*; and *e* by *i*, *a*, *ia*, or *ai*. *H* was sometimes used as a substitute for *g* or *gh*, and *u* for *o* or *y*. *Yr* and *or* or *ur* were used as the final *r*. When the insufficiency of the Runic alphabet became apparent, the letters *e*, *g*, *p*, *r* were added, but they received no special names as the old letters did, nor were they expressed by any new signs, but were mere modifications of the old characters *i*, *k*, *b*, *f*. This alteration was effected by means of one or more dots added to the original letter, and the new characters were called *stun nar runir*, or "dotted Runes." And lastly, when the Roman alphabet became general throughout the North, new characters were formed for expressing the sounds of *ae*, *oe*, *ue*, and the letters *c*, *q*, *x*, and *z*; but these cannot be regarded as genuine Runes, and the same remark will apply to the three double Runes, *al*, *mm*, and *tt*.

The Runic alphabet was also used to express numerals, the old letters being employed as far as sixteen; the double letters, *al*, *mm*, and *tt*, for *seventeen*, *eighteen*, and *nineteen*; *twenty*, and over that, being expressed by two letters: for example, *thurs*, *thurs* = 30, *thurs*, *thurs*, *os* = 34. The Runic characters were most commonly written from left to right, and are seldom found running from right to left. Sometimes they are written from the top to the bottom, and then turn up again; sometimes from left to right, and so back to the left again; and numerous examples of them, written in various ways, may be seen engraved in the 'Archæologia,' especially in vol. 28, pp. 338-9.

Runic inscriptions or writings were divided into different classes, from the subjects of which they treated. Thus, Runes imprecating wrath or vengeance upon enemies were called *noxious* or *bitter Runes*; those which were used for deprecating misfortune or disgrace were styled *propitious* Runes; those which invoked victory were known as *victorious* Runes, and those which applied to the healing art were *medicinal* Runes. All these Runes were considered powerful in producing the effect sought by them; and they were consequently employed, not only for the purposes mentioned, but also as antidotes against poison, as love charms, as efficacious in preventing accidents by land or sea, as dispellers of unhappy thoughts and gloomy forebodings, as foretellers of future events, as guards against the evil eye and the jealousies and snares of enemies—in a word, for whatever end might be desired for the person who inscribed them. In order, however, to render them suited to their respective purposes, various ceremonies were observed in writing them, each kind of Rune having its proper material and place for inscription; the shapes of their arrangement being those of serpents, circles, triangles, and similar mystic figures, according to the event which they were intended and expected to bring to pass.

Below is the Norse Runic alphabet. The reader is referred to vol. xxviii., pp. 338, 350, 352, 366, of the 'Archæologia,' for examples of various forms of Runic letters and inscriptions, which are inserted in an able essay of the late John M. Kemble upon Anglo-Saxon Runes.



Runic inscriptions exist upon rings, medals, coins, monumental stones, crosses, and sides of rocks, and a curious one may be seen upon a sword-blade in the Department of Antiquities in the British Museum. They have been discovered in Norway, Sweden, Denmark, in parts of the British Isles, Germany, France, and Spain, in fact wherever the Teutonic race settled itself during the early period of its migrations in the 4th and 5th centuries after Christ.

The most useful information with regard to Runes and Runic inscriptions will be found fully given in Planta's 'Essay on the Runic or Scandinavian Language;' Olaus Wormius, 'Lexicon Runicum;' W. C. Grimm's work, 'Über Deutsche Runen;' Mallet's 'Northern Antiquities;' Hicke's 'Thesaurus Linguæ Septentrionalis;' articles in the 'Archæologia,' the 'Journal of Philosophical Transactions,' and several other philological journals, in which the references required will be found by consulting their respective indexes.

RUPTURE. [HERNIA.]

RURAL DEAN. [DEAN.]

RURAL ECONOMY. The whole subject of agriculture, with all its details, might properly be discussed under this heading: most of it is, however, referred to piecemeal in the various agricultural articles which will be found throughout the Cyclopædia, and it remains here to do little more than enumerate those more general relations of country life, and of the several classes interested in the ownership and cultivation of the land, which have not yet been named.

The common weal depends in great measure on these relations tending to the highest productiveness of the land. We want wealthy landowners in order that any hindrance to the proper cultivation of the land, which stagnant water, defective farm-buildings, and poor cottages present, may be removed. We want enterprising, intelligent, and wealthy farmers, in order that a good machine, which an estate properly equipped undoubtedly is, may be worked to its utmost capabilities; and we want steady, domestic, intelligent, and well-conditioned labourers, because without them it is impossible to carry out the cultivation of the land perfectly.

Under the first head the legislature has granted facilities to the owners of land, and even to the owners of a limited interest in it—as in the case of the life-tenants of settled estates—for borrowing money on land in order to the execution of such works as may tend to its permanent improvement, in the way of draining, roads, fences, farm buildings, cottages, &c.; and there are many companies and associations prepared to carry out such improvements, in return for a rentcharge on the property during a sufficient term of years for their repayment. The legislature has not yet, however, conferred all the facilities required; for landowners are often disabled by the refusal of neighbouring proprietors to concur in schemes for their mutual benefit. This is especially the case where an outfall is needed for the drainage of the property, and can only be obtained through the fields of another. A refusal by a neighbouring proprietor can at present be overruled only by an exceedingly costly and litigious process, and no such difficulties ought to exist in the way of anything which so much concerns the general interest. It is anticipated that a measure will, during the current session of parliament (1861), be introduced by government for granting the facilities required.

Leaving the subject of the relations of landowners to each other, we come to those existing between them and the tenantry on their estates. Under this head the relative merits of tenancy-at-will and of leases for periods of varying duration, of the provisions for ensuring to the tenant the return of all his property spent in cultivation, in the event of his leaving, and the conditions generally under which land is "let" to the cultivator of it, would need to be considered. But on these points we have merely to remark in general, that provision for the security of the tenant's capital when invested on another's land is obviously necessary to the prosperity of agriculture. Such provision is in many districts believed to exist in a long family connection between owners of land and their tenantry, which neither of them willingly break, though instances every now and then occur to show the instability of such arrangements; it is elsewhere made by so-called "tenant-right" agreements, which, co-existent with the right of the owner to give his tenant six months' notice to quit, ensure that the latter should receive on leaving a certain proportion of his expenditure under many different heads, varying in quantity with the period which has elapsed since such expenditure has been incurred. This is the system which prevails in Lincolnshire, and under which large portions of that county have wonderfully increased in fertility. The most efficient way, however, in which the property of the tenant is secured to him, is by a lease of the land for a sufficiently long period to ensure the full fruition of all his plans of improvement and good cultivation. It is in this way that Scottish agriculture is generally so good and Scottish rents are so high.

Lastly, there exists the relation between the labourer and his employer, on which good agriculture very materially depends. The landlord should provide adequate cottage accommodation, and it is the interest of the farmer to attach his labourers to him by personal interest in their welfare, by the payment of wages according to the real merit of the men, and the value of the work they do, rather than by a common rate per diem, including all alike without regard to differences of merit, and thus discouraging individual effort at improvement. The adoption of the allotment system, by which each cottager becomes, at a moderate rent, the tenant of a large garden, either close to his dwelling or in common-field, along with all the others in the village, has the best influence on the character and comforts of the labourer.

RUSH; RUSHES. This material, which is used to some small extent in the arts, is the *Equisetum hyemale*. The stem is very rough, with from fourteen to twenty slender furrows. It is a native of England, Scotland, and Ireland, as well as the continent of Europe; but is almost unknown in the middle and southern English counties, and is only sparingly distributed anywhere. It appears to possess tannin, and to act as an astringent. It is supposed to be injurious to cows, and is said to cause their teeth to drop out; but horses eat it with impunity. This plant, more than any other species, is used for the purposes of polishing. Lightfoot says, that in Northumberland the milk-maids scour their pails with it. Rush is also used for the purpose of polishing wood, bone, ivory, and various metals, particularly brass. It is brought into this country from Holland, where it grows abundantly, and is sold in the shops of London under the name of Dutch Rush.

The well-known *rushes* of country places belong to a different genus of plants from the Dutch rush. They come under the genus *Juncus;* of which one species, the common soft rush, is to be found in most moist pastures, by the sides of streams, and under hedges. In some districts these rushes are used by the poor as a substitute for candles. They are gathered in summer and autumn; the largest and longest being deemed the best. They are kept in water until they are to be peeled; which process consists in divesting the rush of its peel or rind, so as to leave one regular narrow rib from top to bottom, to support the pith. The rushes are then bleached on the dewy grass, and dried in the sun. These rush-piths are finally dipped into any kind of fat or grease, until they acquire a coating analogous to that of a candle. In the bacon districts of Hampshire, hog's fat is employed for this purpose. When White wrote his well-known 'Natural History of Selbourne,' he strongly recommended this feature in domestic economy; but it is possible that the cheapening of candles has lessened the relative advantage of the more primitive system. Rushes are, however, more ordinarily used for plaiting into mats and chair-bottoms, and for constructing small toy baskets. The wicks of rushlights are made of the pith.

RUSH-BEARING, another name in some parts of England for the country wake. It appears that in ancient times the parishioners brought rushes at the Feast of Dedication, wherewith to strew the church, and from that circumstance the festivity itself obtained the name of Rush-bearing. The country wake occurs by this name in the glossary of the Lancashire dialect. In the parish accounts of St. Margaret's, Westminster, is this item, under the year 1544:—"Paid for rushes against the Dedication Day, which is always the first Sunday of October, 1*s.* 5*d.*" Notices of the custom of rush-bearing, as used in various parts of Derbyshire, will be found in Glover's 'History and Gazetteer' of that county, vol. i. (Brand's 'Popular Antiq.,' vol. i.)

RUSHES are well-known plants which appear in all soils, especially those which are fertile, when the water which cannot be evaporated remains in a stagnant state under the surface. They are most common on moist meadows with a retentive subsoil; and as they not only occupy a space which might produce good herbage, but also greatly deteriorate the hay with which they are mixed, every means to destroy them are employed by industrious farmers. Formerly in this, as in most other instances of defect in the soil, only a temporary remedy was generally thought of. The rushes were mown down at particular times of the year, alkaline ashes and salt were spread over them, and in some cases they were destroyed by pouring boiling water on the roots. But all these only killed the individual rushes, without removing the immediate cause of them, or correcting the stagnation of water which invariably reproduced them. The only effectual cure for rushy grounds is a complete system of draining. The truth of this assertion is so generally admitted, that it is unnecessary to dwell upon it. Wherever the land can be effectually under-drained, rushes will generally disappear as by magic. If they are strongly established in the soil, it may take some time before they completely die away, even after drainage, at least in pastures which are not broken up; but if the land is ploughed and has a proper tillage, they will not survive the first year. In rich old meadows, which it would not be prudent to plough up, they may be destroyed by mowing them when they are in bloom, and immediately spreading ashes or salt over the place where they grew. This repeated twice will clear the ground entirely, and the draining will prevent their reappearing.

In heavy grounds which have been laid up in high ridges without thoroughly draining the land, and sown with grass-seeds to remain in pasture two or three years, it is not uncommon to see every interval between the stetches filled with rushes, especially if the land be reduced in fertility by overcropping. This indicates a wet subsoil, and suggests under-draining; but the rushes are often caused by the very roundness of the ridges, which is supposed to keep the land dry, but which accumulates the water in the furrows. If the land had been laid quite flat, it might have been too wet to produce good crops of wheat, but rushes would not have appeared. In very flat meadows rushes are only found where the land lies very low, with an impervious subsoil, or a want of inclination in the surface to carry off the superfluous water. What might at first sight be considered as an anomaly, is yet perfectly true—no rushes are found in the best water-meadows, although they are for a considerable portion of the year entirely soaked in water; but the water is never allowed to stagnate for a moment, and is always kept running on and off.

The great advantage which has been obtained by the system of thoroughly draining compact soils, or those which rest on impervious subsoils, has induced proprietors and farmers of land to employ their capital in this most certain of all improvements, and the consequence will be, that in a few years rushes will only be seen in those low and unprofitable spots from which the water cannot be drawn off by drains, and where they will supply some small resource to the maker of mats and the repairer of rush-bottomed chairs.

RUSSIAN CHURCH. [Greek Church.]

RUST, in the common acceptation of the term, is the red pulverulent substance which is formed on the surface of iron when exposed to air and moisture. It is an oxide of iron, and in point of fact other metallic oxides may be considered as rusts of the peculiar metals which they contain; the term is however limited in application to the red oxide or per- or sesqui-oxide of iron. [Metals. *Iron, peroxide of.*]

RUSTIC or **RUSTICATED WORK**, in architecture, a species of decoration for walls, wherein the joints between the courses, and between the separate stones in each course, are strongly defined by sunk channels or grooves. Although an imitation of what would in itself be offensive, and therefore at first apparently quite at variance with good taste, this mode is only a legitimate, artistical, or æsthetical imitation, suggested by accident or defects. The expression, originally derived from rudeness and coarseness of execution, from large stones irregularly put together, without their edges being smoothed and fitted to each other, is here only partially retained so as to indicate boldness and strength, and also a certain attention to finish and to regularity in the symmetrical arrangement of the courses and stones. There is a studied intention manifested, which prevents our confounding the imitation with what furnished the hint for it. In reality rustication contributes in an eminent degree to richness of surface, and it was accordingly frequently employed by the ancients—by the Romans at least, not only in those works which were characterised by massiveness and by a certain degree of rudeness, such as amphitheatres, bridges, &c., but on the exterior of temples and other edifices, on which the most finished decoration was bestowed. For not only does rusticating the face of the walls occasion contrast, and thereby tend to set off columns or pilasters to greater advantage, but the lines and shadows so produced remove that blankness which might otherwise attend too much uniform plain surface.

Besides being different from plain masonry, rustication admits of great variety, both in regard to design and execution, and of great diversity of character, from severity and heaviness to studied elegance. The most obvious distinction is that arising from the surfaces of the rustics, according as they are either *plain* or *rough*; and if the former, they may be either *smooth*, or *hammer-dressed*, that is, left slightly chipped; else *tooled*, or with the marks of the chisel. Or if intended to be rough, the rustics may be *vermiculated*, *hatched*, or *frosted*. The first of these modes is produced by cutting deep hollows into the surface, the second by making it jagged and rugged, while the third consists in giving a delicate crispness like frost-work to the stone.

As regards *jointing*, there are two modes: one in which the channels between the stones are *grooved*, or form rectangular sinkings; the other in which they are *chamfered*, that is, the edges of the stones are bevelled off in such manner that the section of the joints forms a rectangular triangle. Neither are the above by any means all the varieties, as will be seen by some examples at the end of this article, which cannot be very well explained without cuts. Great variety of character and design may further be produced by an intermixture of the different modes,—for instance, by smooth and rough rustics together, or by different kinds of rusticating for different stories, the bolder and coarser being placed below and the more delicate above.

Italian architecture presents many fine studies and examples of rusticated work. The Florentine style—which, it may be observed, is the direct antithesis of the Palladian—shows what may be accomplished by little more than rustication alone. If it be severe, it is also simple, yet rich and dignified.

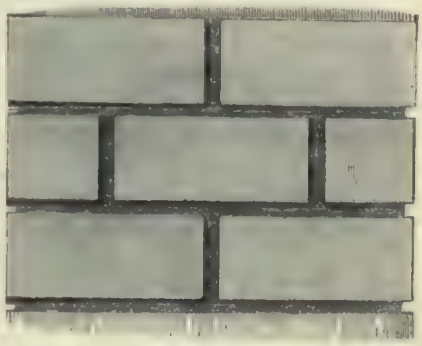
In this country we have very few examples of rusticated work upon a grand scale: for here it is almost entirely confined to basements. It is scarcely ever employed as the general decoration of an entire front, except it be occasionally for prisons, for which it is certainly appropriate, though it does not therefore follow that it is unsuitable where richness and magnificence are more required than severity.

Much of the beauty of rusticated fronts depends upon the form and proportions of the arches or openings, and on the arrangement, &c., of the rustics which form the voussoirs either to arched or straight-headed windows. Occasionally, moulded archivolts are substituted for radiating voussoirs, but the effect is not good, because they cut the horizontal joints of the courses very disagreeably; which, it may be observed, is likewise the case where the voussoirs form an *extrados* either concentric with the arch, or making a more elevated curve, as in most of the Florentine examples. It is far better to make the voussoirs *elbowed*, so as to unite with the horizontal courses, whereby the whole looks firmly bonded together. Sometimes imposts to arches are omitted altogether, or if there be such member, it is usually a mere plat-band, although occasionally it is moulded. In arches the keystone may either be similar or distinguished from the other voussoirs; which last may be done in a variety of ways, although the most usual one is to cut it into the form of a console, or else enrich it with a mask sculptured upon it, of which kind are the keystones to the arches of the Strand front of Somerset House, representing the nine principal rivers of England, personified as old men. *Bossages* is a term more particularly applied to rusticated cinctures on the shafts of columns, which may be either square or cylindrical, but should not greatly exceed the diameter of the shaft itself, more especially in the former case. Columns of this kind ought invariably to be engaged, and the wall behind them of course rusticated also. In such case the cinctures serve as ligatures to bind and incorporate them with the rest, whereas insulated columns with blocks upon their shafts are equally unmeaning and uncouth. The same remark applies to rustic blocks stuck at intervals upon the architraves of doors and windows, as, for instance, those of St. Martin's Church, London, although there is no rusticating in that building. Of columns with bossages or rusticated cinctures, the two arches within the court of Somerset House are a tastefully-designed and well-executed example.

The following are some of the varieties of rusticating above referred to, drawn sufficiently large to show the precise form and section of the joints or grooves:—

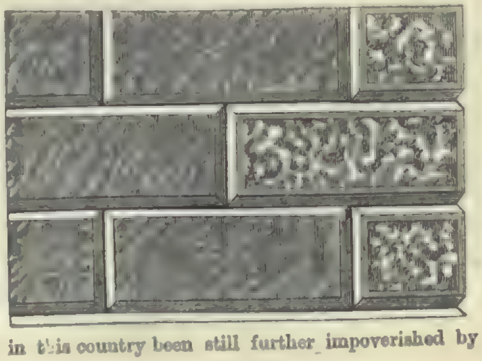
No. 1. Rustics with rectangular joints or channels.

No. 1.



Rustics of this kind have always plain faces. French or horizontal rusticating, without vertical joints, has generally rectangular channels; this sort of rusticating, or pseudo-rusticating with horizontal joints only, has in this country been still further impoverished by making

No. 2.

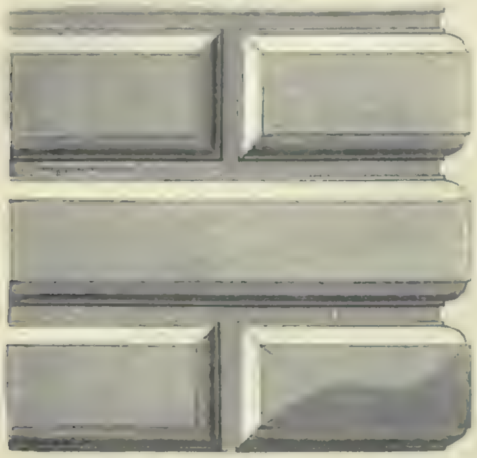


the channels broad and shallow, and the courses so deep that there are only a *few* horizontal streaks along the face of a wall.

No. 2 is an instance of chamfered joints and vermiculated rustics, bordered, that is, having a plain surface around their faces.

No. 3 shows an example of Florentine rusticating with moulded channels, the effect of which is particularly rich. One of the rustics is *facetted* in the cut, in order to give an example of that mode in rusticated quoins.

No. 3.



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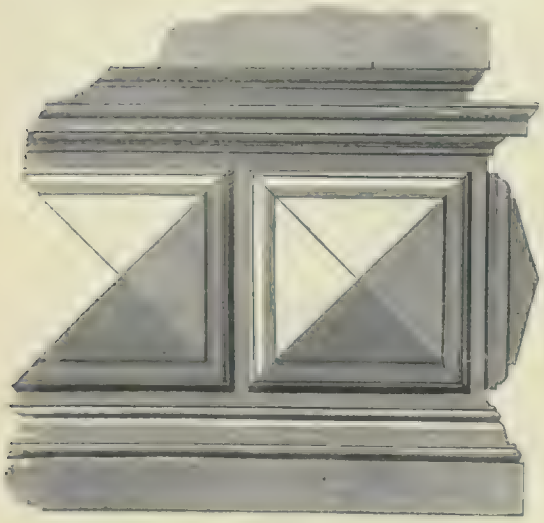
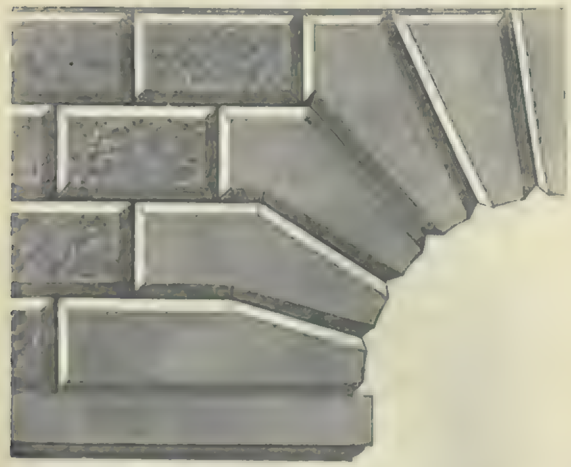


No. 5.

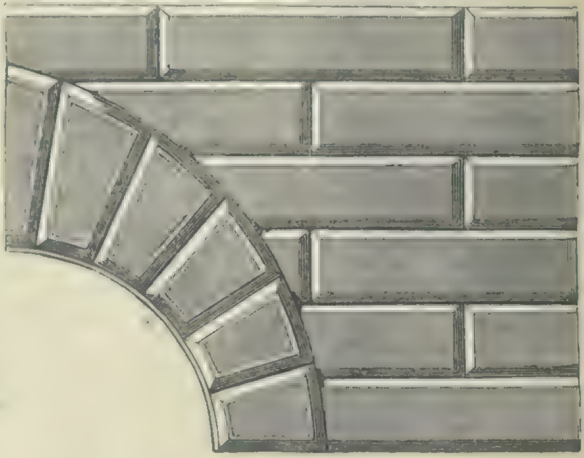


No. 4 is another mode peculiar to the Florentine style, in which the rustics are *facetted*, or cut so as to form four triangular surfaces. It is not used throughout, but only in the lower course, forming a sort of dado to the building. This example is from the same building as the preceding.

No. 5 shows one-half of a rusticated arch having *elbowed* voussoirs running into the horizontal courses.

No. 6 represents half of another arch with voussoirs whose *extrados* form an eccentric curve from that of the arch itself, or else a pointed arch, while the *intrados* form a semicircular one.

No. 6.



RUTAMIDE. [RUTIC GROUP.]

RUTATES. [RUTIC GROUP.]

RUTH, BOOK OF, an acknowledged canonical book of the Old Testament, though Bertholdt and some other German writers have considered it a fiction or parable. The history of Ruth seems to have been inserted in the sacred canon as a necessary link in establishing the pure genealogy of David, and consequently of the Messiah; and perhaps also to furnish a record of the fact that one of the Messiah's ancestors was a Gentile, thus intimating the truth that the Gentiles were to have a part in the highest privileges of the Jews. In the ancient Jewish canon this book forms a part of the Book of Judges, because the events recorded in it happened during the rule of the Judges. Its exact date is however uncertain, but most probably the famine mentioned in verse 1 is that which happened in the time of Gideon, about B.C. 1241. It is generally supposed to have been written by the prophet Samuel. The style is marked by a touching simplicity, and some parts of it are very pathetic. (The *Introductions* of Jahn, Eichhorn, De Wette, and Horne; Umbreit, *Ueber Geist und Zweck des Buches Ruth*, 1834.)

RUTHENIC ACID. [RUTHENIUM.]

RUTHENIUM (Ru). This metal was shown to exist in platinum ores by Clauss in 1845. According to Deville and Debray, who have specially studied the metals associated with platinum, ruthenium may be prepared from the native osmide by mixing it, in fine powder, with three parts of binoxide of barium and one of nitrate of baryta; heating the whole to redness in a crucible for an hour; treating the product with hydrochloric, nitric, and sulphuric acids consecutively; precipitating with chloride of ammonium; igniting the precipitate; and finally fusing the residue with nitrate and hydrate of potash. From the rutheniate of potash thus formed, the *teroxide of ruthenium*, or *ruthenic acid* (RuO_3), may be precipitated by carbonic or nitric acids, and then reduced to the metallic state by heating in a current of hydrogen.

Ruthenium is only fusible with extreme difficulty. It has a blackish-brown surface, and is hard and brittle like iridium. Its specific gravity is 11 to 11·4, and its equivalent 52·11.

Ruthenium and *oxygen* unite in four different proportions. *Protoxide* (RuO); *sesquioxide* (Ru_2O_3), the most stable of these oxides, formed on igniting the metal in a current of air; *binoxide* (RuO_2), obtained by roasting and igniting the bisulphide; and *ruthenic acid* (RuO_3), prepared as already described.

Ruthenium and *sulphur*. The sulphides of this metal are probably as numerous as the oxides, but they are very difficult of preparation.

Ruthenium and *chlorine* form three compounds. The *protochloride* ($RuCl$) results from the ignition of the metal in chlorine gas; it is insoluble in water or acids. The *sesquichloride* (Ru_2Cl_3) is formed on dissolving the sesquioxide in hydrochloric acid; and the *bichloride* ($RuCl_2$), which exists as a rose-coloured double salt with chloride of potassium.

The salts of ruthenium are chiefly those of the sesquioxide. They have a yellow colour, and alkalies re-precipitate from their solutions the sesquioxide as a black powder. A *sulphate*, containing $RuO_2,2SO_3$, has been obtained.

RUTIC ACID. [RUTIC GROUP.]

RUTIC GROUP. A cluster of chemical substances containing the electro-negative radical *rutyl* ($C_{20}H_{19}O_2$).

Hydride of rutyl ($C_{20}H_{19}O_2$, H) *rutic* or *Capric aldehyd.* This body forms the greater part of the volatile oil of the common rue. [RUTA, *graveolens*, in NAT. HIST. DIV.] Its specific gravity is ·837; boiling point from 442° Fahr. to 446° Fahr.; vapour density 5·83. It crystallises in transparent plates at a few degrees below the freezing point of water; gives crystalline combinations with the alkaline bisulphites; is but little acted upon by sulphuric or hydrochloric acids, but is converted into *rutic acid* when placed in contact with nitric acid.

Rutic acid ($C_{20}H_{20}O_4$) or *capric acid.* This acid may be obtained from sources other than just mentioned. It is one of the products of the saponification of butter; it may be formed by the action of nitric acid upon oleic acid; it is contained in small quantity in cocoa-nut oil, and is also found in the oily matters that accompany the distillation of Scotch whiskey. From the latter source it is most conveniently obtained, though the operation is tedious and somewhat difficult.

Rutic acid is crystalline and colourless; it has an odour recalling that emitted from the skin of a goat, melts at 81° Fahr., is very soluble in alcohol or ether, is not soluble in cold water, but is slightly so in hot water. It is monobasic and forms crystalline salts termed *rutates.*

Rutic ether ($C_{20}H_{19}(C_4H_5)O_4$) separates as an oily liquid on passing dry hydrochloric acid through a solution of rutic acid in absolute alcohol. Its density is 0·862. Ammonia converts it into *rutamide.* The latter body crystallises in brilliant plates.

RUTILE. [TITANIUM.]

RUTILIN. [SALICYLIC GROUP.]

RUTINIC ACID. ($C_{12}H_8O_6$) A crystalline acid contained in the stems and leaves of rue. It is insoluble in cold water and ether, but readily dissolves in boiling water or alcohol. When an alcoholic solution of chloride of calcium is added to an alcoholic solution of rutinic acid, a bright green precipitate is thrown down.

RYE is a plant of the family of the Gramineæ, and bears naked seeds on a flat ear furnished with awns like barley. The straw is solid, the internal part being filled with a pith, which, if it causes it to be inferior as fodder, makes it more valuable for litter, and particularly for thatching. The value of the straw is often nearly equal to that of the grain. Rye grows on poor light soils which are altogether unfit for wheat, and hence tracts of light sands are often denominated rye-lands. On these soils this grain is far more profitable than wheat, which can only be raised there at a great expense of marling and manuring. The value of rye in those countries where it forms a considerable portion of the food of the labouring classes, is from two-thirds to three-fourths of that of wheat. From experiments made to ascertain the quantities of nutritious matter in rye and wheat, Thaer states their real comparative value to be as 64 to 71. It was formerly raised in considerable quantities in England, either alone or mixed with wheat, and was then called *meslin*, from the old French word *meslé*, which means *mixed.* The meslin when ground produced a very wholesome and palatable household bread, and it was thought advantageous to sow the two sorts together, from the notion that if either failed there would still be a crop of the other. This, however, was an error. No doubt the wheat would often fail on inferior soils when the rye would thrive; but the reverse was seldom or never the case; and besides the rye comes to maturity at least a fortnight before the wheat. If the soil is capable of bearing a moderate crop of wheat, it would be much more advantageous to sow one portion of a field with rye and another with wheat; and if meslin bread is desired, the two grains may be mixed in any required proportion. Excellent bread is made of two parts of wheat and one of rye ground together, with only the coarse bran sifted out.

Rye is at present raised in very small quantities in England. It is however extensively cultivated on the Continent, especially in the Netherlands, where it is the chief grain from which the spirit commonly called Hollands is distilled, which is flavoured with juniper, in Dutch called *Genever*, whence the name of *geneva* and its contraction *gin.* When malted it makes excellent beer, one bushel of rye malt being equal to at least one and a quarter of barley malt. The cultivation of rye is very simple; it is usually sown 2 or 3 bushels per acre after wheat, where the soil is light and rich, or after turnips and potatoes, in those soils which are not strong enough for wheat. As it is ripe in June or July, turnips are often sown immediately after; and by the manure produced by these, as well as their effect on the soil, a second crop of rye can be obtained the ensuing year. This is no doubt contrary to all sound theory; but such is the practice in Flanders, and they do not find that their crops diminish in consequence.

In England rye is mostly sown as a green crop, and when fed off early in spring with sheep, the land is invigorated, and will bear excellent potatoes or turnips the same year. This practice cannot be sufficiently recommended; and if the rye is sown very early in autumn, it may be fed off in October and November, when sheep-feed is beginning to fail and the turnips have not yet attained their full size, with little detriment to the succeeding spring produce.

Winter barley and winter oats have been substituted for rye as spring fodder by some farmers; but on land of moderate quality rye is generally preferred. It bears the severest winters, which is not the case with barley or oats.

The preparation of the land for rye is the same as for wheat, except that in very light soils no more ploughings are required than will clear the ground of weeds. If rye is sown after harvest, one ploughing only is usually given. It will thrive upon rich wheat soils, as well as upon lighter, and, as it throws out numerous stems in rich land, it is the more profitable as fodder, although the crop of grain might not be so abundant when the plants are too much crowded. To have as much green food as possible, the rye is always sown broadcast, three bushels at least to an acre; some sow a sack, and with advantage. It is also usually sown amongst winter tares, which the stems of the rye help to keep up from the ground: half a bushel of rye to three bushels of tares is a fair proportion; some farmers sow wheat instead of rye, as being stronger in the stem, but besides its being more expensive, it does not shoot so early as rye, nor is it so much stronger in the green stem, as is supposed. Oats are invariably sown amongst spring tares, and answer the purpose well.

There is a variety of rye mentioned by continental authors by the name of *Seigle de la St. Jean*, or St. John's-day rye, because it grows so rapidly that if sown about St. John's Day (24th June), it will be fit to mow green by the middle of September, and in favourable seasons may be fed off again in November, without preventing its giving ample feed in spring, and a good crop of grain at the next harvest. It has been introduced into England, but whether or not owing to its character not being maintained, it has not maintained its reputation. There is no doubt that there are varieties of the same kind of plants which have a much more vigorous vegetation than those commonly cultivated; and the introduction of them where they are not known is an important benefit to agriculture. The celebrated agriculturist Du Hamel du Monceau mentions an individual who had obtained, from one sowing, five abundant cuts of green rye for cattle in two years. If any green plant is cut down before the fructification is completed, it will in general throw out fresh stems; and in very rich soils its blossoming may thus be continually retarded, until the roots become too weak to force successive stems.

When the land is in good heart and clean after wheat-harvest, it may be expeditiously cultivated by means of a strong scarifier, or some similar instrument, which opens the soil several inches deep, without turning it over; and rye may be sown immediately, without using the plough. This is an immense saving of time and labour, as four or at most six horses will completely stir ten acres of land in a day, which may thus be immediately sown before the wheat is out of the field, or fit to be carried. A week gained in the time of sowing may make all the difference between a crop which can be eaten off before winter and one which will only be fit for the sheep in the succeeding spring. The weeds which may spring up with the rye will either be choked by its luxuriance, or at all events will never shed their seeds, being mown or fed off with the rye, and the roots ploughed in the next year. The large perennial roots will thus be more easily taken out by the harrows, and all the annual weeds will be destroyed.

Although the value of rye as a green crop is fully admitted in England, very little is grown for food or distillation; yet on some poor soils, where wheat and barley are now often sown with a very poor return, and at a great expense of manure, rye and buckwheat would give a much greater clear profit, and would require much less manuring: and where there are not ready means of improving the soil by claying or marling, the cultivation of rye would be found most advantageous; and, by means of sheep, very poor sandy soils might thus be made profitable.

Rye is subject to most of the diseases which attack the plants of the family of the Gramineæ, such as rust, mildew, burnt-ear, and smut-ball. These diseases are described in the article WHEAT. But there is one remarkable disease, which, although sometimes found in wheat, is much more commonly observed in rye. It is called the *ergot*, the French name of a cock's spur, which the diseased grain resembles in shape. [ERGOT.]

RYE-GRASS, sometimes called *Ray-Grass*, is one of the most common of the artificial grasses; it is of the family of the *Gramineæ* of the genus *Lolium.* There are several varieties, some annual and others perennial, some producing a strong juicy grass, and others a small diminutive plant. These varieties arise chiefly from difference of soil, climate, and cultivation. In the convertible system of husbandry, rye-grass performs a very essential part, especially the perennial sort, which, mixed with different varieties of clover and other grass-seeds, produces a rich and close herbage, which may be either mown for hay or depastured. In the course of two or three years the land is so much recruited by the extension of the roots, and by the dung and urine of the animals, that, without dung from the yard, it will produce one or two very good crops. When clover is sown to remain only one year, the annual variety of rye-grass is frequently sown with it. It adds to the weight of the hay, and the stems of the rye-grass are a good corrective to the richness of the clover, when they are given to horses in a green state; but when the hay is intended for the London market, or that of any of the great mercantile towns, the tradesmen and carmen prefer the pure clover hay, thinking it more nutritious. Those who cultivate their land on the Norfolk system have a prejudice against rye-grass, as being unfavourable to the succeeding crop of wheat. Accordingly, when they have a layer of rye-grass, instead of clover (because the clover, having been too often repeated, fails in the ends, they often take peas or beans between the rye grass and the wheat. This accords with theory; for when the rye-grass completes its fructification, even if the seed is not ripe, it has a deteriorating effect on the soil similar to that of a white crop, and therefore a leguminous crop should succeed it.

Different varieties of rye-grass have been recommended at various times; one which goes by the name of *Pacey's rye-grass* has kept its reputation as a perennial grass for a long time. The *Italian rye-grass*, well known in the south of France, in Switzerland, and in Germany, is a native of Lombardy, where it grows most luxuriantly and rapidly by means of irrigation. There is no grass which so soon forms a water-meadow; and it bears well the cold and wet winters of Britain. On rich moist land it grows most rapidly and luxuriantly. It will bear several cuttings in a season. Those who have paid attention to the cultivation of rye-grass think highly of it. It grows much more rapidly in spring than any other grass, and is so much relished by cattle, that they scarcely allow a single stem to spring up. A small space in a layer being sown with Italian rye-grass, may be distinguished in the pasture by its superior green colour and its very close pile; and the cattle will always be found there, as long as there is the least bite for them. It may be advantageously sown in autumn with the Trifolium incarnatum, and together they will give much early green food in spring. It may be a question whether this is preferable to sowing rye; but it affords a variety, and on some soils may produce earlier and more abundant feed for lambs. When Italian rye-grass is sown by itself, and allowed to go to seed, it becomes thin after the first year, from many of the plants dying off: it may therefore be prudent to mix some other kinds of grasses with it, which will supply its place where it is worn out. It is a most excellent practice to sow Italian rye-grass on old meadows and pastures, at the time when they are recruited with compost or earth. If they are well harrowed or scarified, and the rye-grass be sown before the roller goes over them, the succeeding crop of hay will be much increased in quantity and improved in quality. On water-meadows, which require renovation, this grass is invaluable, being early, rapid in growth, and very abundant when irrigated. We have seen hay made in July from a newly-made water-meadow sown with Italian rye-grass in March. This was at Mr. De Fellenberg's, at Hofwyl, near Berne, in Switzerland. No plant will more fully use abundant dressings of manure than Italian rye-grass. If richly manured and irrigated after each cutting it will yield 18 to 20 tons of green food per acre, three or four times in the year. When sown by itself 3 bushels per acre are sown broadcast in August or September, and the next year the crop will be in full bearing. A first or second cutting may be taken in the following year, and being then ploughed down a crop of late turnips or rape may be taken previous to a succeeding spring-sown corn crop.

RYE, SPURRED. [Ergot.]

RYOTS, the name by which the cultivators of the soil in Hindustan are designated. The ryots pay rent out of the produce of their land to a sovereign proprietor, and, so long as they pay the rent demanded of them, have a claim to the continued occupation of the land.

The economical condition of the Asiatic cultivator may be described as being made up of the three following circumstances:—1. He is an hereditary occupier, or, in other words, has an hereditary claim to the occupation of the land which he cultivates. 2. The amount of rent which he pays is, in practice, determined by the sovereign power. 3. There exists a number of classes intermediate between the hereditary occupier and the sovereign, all entitled to various portions of the revenue which is yielded by the land, but none having any proprietary right. The number of these intermediate classes, arising out of the tendency of all offices connected with the land to become hereditary, has contributed greatly to the ignorance prevalent among Europeans of the position of Asiatic cultivators.

Such being the general features of the economical condition of the ryot, his actual position necessarily depends most on the amount of rent paid by him to the sovereign, and the manner in which the rent is paid.

The amount of rent was fixed by the laws of Menu at a sixth, an eighth, or a twelfth of the crops, according to differences in the soil, in the degree of labour necessary to cultivate it, and in the general prosperity of districts; but in times of urgent necessity, of war or invasion, the same laws allowed the king to take even so much as a fourth. ('Institutes of Menu,' c. iii., 130; x. 118, 120.) A sixth part of the produce had come to be the uniform tax in Hindustan when the Mohammedans became its masters. ('Sacontala.') But we find in Strabo, that when Alexander invaded India, a fourth of the produce was generally taken as rent. The despotic sovereigns of the East did not long continue to observe their ancient laws, sometimes openly violating them, at other times evading them by a resort to indirect taxation. Indeed before the Mohammedan period there are instances of oppression by Hindu governments, under which the ryots were allowed to retain no more than a fifth or sixth of their crops.

The form in which the rent is paid has even a greater influence on the condition of the ryot than its amount. In ancient times the rent was always paid in produce. Whenever, in later times, it has been demanded in money, the consequences have been ruinous to the ryot, chiefly owing to the want of markets. When the ryot is compelled to pay in money, which, owing to the want of a ready market, he has a difficulty in doing, his obvious resort is to a money-lender. The money which he borrows for the purpose of relieving himself of immediate difficulty is borrowed at a high rate of interest. The immediate difficulty is thus got rid of at a great sacrifice, and the ryot becomes dependent on the money-lender. In 1860 considerable discontent was created among the ryots in Bengal by the system asserted to have been adopted by the European indigo manufacturers: these, it was at least asserted by the ryots, made agreements with the zemindars that certain portions of the land should be devoted to the cultivation of the indigo plant, to be sold to them, in consideration of certain advancements of money at a rate which was ruinous to the cultivator. The attempt to enforce these agreements by law occasioned several tumults, and the dispute is not yet (1861) settled.

The agency by means of which the rents are collected, though less important than the form of payment, has also a considerable influence on the condition of the ryot. Under the ancient Indian governments, the agents of the prince to whom districts were assigned transacted immediately with the ryots, either singly or in villages. The latter mode was the more general, by which the government levied a certain sum on each village, and left it to the villages to settle the individual quotas among themselves.

As regards the payment of rents, there were two kinds of arrangement prevailing in the villages. In some villages the land was cultivated in common, and each cultivator had a share of the produce assigned, according to certain fixed rules; these were called *byacharry* (brotherhood) villages. In others, each ryot cultivated separately his own spot of land, and paid rent for it separately: these went by the name of *putterday* (partnership) villages.

The heads of villages paid the rents collected to the heads of districts (*des adikars*); these again to the heads of larger tracts of country. The system of government detailed in the 'Institutes of Menu' enumerates lords of one town or district, of ten towns, of twenty towns, of a hundred towns, and a thousand towns. All these lords received assignments of land, and a per centage on their collections besides.

The heads of districts (*des adikars*) came afterwards to be represented by one class of zemindars, namely, those whose duties were confined to the superintendence of police. The class of zemindars however which is the best known is that class in which the duty of collecting the revenue was added to the superintendence of police. This is not the place to speak of these functionaries, or to trace the changes in their duties and position until the commencement of the British dominion. [Zemindar.]

A full and interesting account of ryot rents will be found in Mr. Jones's *Essay on the Distribution of Wealth and on the Sources of Taxation*. The reader is referred also to Mr. Mill's *History of India*, by Wilson, vol. i.

RYSWICK, PEACE OF. [Treaties, Chronological Table of.]

S

S is the chief sibilant of the English alphabet, and is employed to represent two different sounds, as in *this* and *these*. The word *sugar* would seem to justify the addition of a third sound, *sh*; but in this word the vowel *u*, so often pronounced *yu*, has modified the pronunciation of the preceding consonant. *Syugar* would easily glide into *shugar*. In the Hebrew alphabet, whence those of Europe are derived, a common symbol is employed, with and without an affixed dot, to denote *s* and *sh*. The symbol referred to has for its name a word which also signifies *tooth* or *teeth*; and if we call to mind that the so-called Phœnician and Samaritan alphabets give older forms of the Hebrew letters than those now used, it will be easily believed that the symbol in its original shape [ALPHABET] was the representation of two or three teeth: an origin which would agree with the fact that the sibilants are all formed by means of the upper teeth, and the sound *sh* by the upper and lower brought together. This explanation is confirmed by the consideration that in emitting the last-named sound the teeth are not only the sole organs employed, but more than usually exposed to view by the retraction of the lips. But for the strong evidence thus furnished by the Hebrew alphabet, the form and power of the letter might have been readily derived from an imitation of a hissing snake.

The letter *s* is subject to the following interchanges, many of which have been previously noted.

1, *s* with *d*. See D.

2, *s* with *th* and *sth*, as in the Laconian dialect of the Greek language, in which θεος, Τιμοθεος, Αθηναια, take the forms σιορ, Τιμοσεορ, Ασαναια. Hence too τυπτομεσθα, &c., readily glided into τυπτομεθα, &c. The English language formerly wrote *loveth*, *hateth*, but now prefers *loves*, *hates*.

3, *s* with *t*. Thus again the Attic forms φησι, επεσον, Ποσειδων, συ, were by the Dorians written φατι, επετον (regularly enough from the present πιπ(ε)τω), Ποσειδαν, τυ. In like manner the German words *das*, *was*, *es*, *wasser*, *hassen*, *essen*, appear in English as *that*, *what*, *it*, *water*, *hate*, *eat*.

4, *s* with *z*. Thus the Greek island Ζακυνθος was the mother city of Saguntum in Spain, and no doubt gave its name to it. In fact the manuscripts of Livy (xxi. 7), with one exception, scarcely worth mentioning, appear to have all got *Oriundi a Sagunto insula dicuntur*, not *Zacyntho*. But the most abundant evidence of the interchange is to be found in the Somersetshire dialect of our own tongue.

5, *s* with *sh*. Witness the Berlin pronunciation of all German words beginning with *st*. Moreover, the English words *sleep*, *slay*, *smear*, *snow*, have for their German equivalents *schlaf*, *schlag-en*, *schmier-en*, *schnee*.

6, *s* with *c*, *g*, and *h*. See those letters.

7, *ks* with *g*. See X.

8, *s* with *n*. See N.

9, *s* with *r*. See R.

10. *S* often appears before an initial consonant, where it is doubtful whether the older form be that with or that without the sibilant. Thus the Greek στεγω, σφενδονη, σφηξ, correspond to the Latin *tego*, *funda*, *vespa*. So σκελος and σκολοψ would be found upon close examination to be the equivalents of the Latin *crus* and *crux*, and σκαλευω to differ from *scru-ta-ri* only in the fact that the latter is a frequentative verb. Again the Greek possesses within itself the double forms σμικρος and μικρος, στρεφω and τρεπω. The English language contains numerous examples of the same variation, as in *melt* and *smelt*, *tumble* and *stumble*, *pike* and *spike*. The German as well as our own tongue not unfrequently prefixes an *s* when the Greek and often the Latin are without that letter. Thus the Greek κλει-ω (root κλεις or κλειδ), the Latin *claud-o* or *clud-o*, and *clavis*, the German *schliess-en*, and the English *shut* are all of one kin. Compare too the various forms of the words signifying *snow*.

11. The sound *sw* at the beginning of words is often degraded by the loss of the sibilant or *w*, or both. Thus to the Latin *suavis* and *suadeo* correspond the Greek ἁδυς, &c., the German *süss*, and the English *sweet*. Those who doubt the connection here assumed between *suavis* and *suadeo*, may, as regards form, compare *clavis* and *claudo*, or *viginti* with what must have been its older form, *duiginti*, while the connection in meaning will be readily established by the common comparison of *advice* with *medicine*, *unpalatable* but *salutary*, as in Lucretius (i. 935), *Sed veluti pueris absinthia*, &c. Again, *sop-or* and *somnus* (*sop-nus*) of the Latin correspond to the Greek ὑπ-νος, to the Gothic verb *in-swepp-an*, the German *schlaf*, and the English *sleep*; *socer* and *socrus* in Latin, to the Greek ἑκυρος and ἑκυρα, and the German *schwieger* as prefixed to *sohn*, *vater*, &c.; the Latin *sud-or*, to the Greek ἰδ-ος, ἱδρως, &c., to the German *schweiss* and English *sweat*; the Latin *sui*, *sibi*, *se*, to the Greek οὑ, οἱ, ἑ, although the Greek has also allied words beginning with σφ. The Latin *soror*, German *schwester*, English *sister*, have lost their correlative in Greek. Lastly this interchange will perhaps account for the fact that the river Oder has two ancient names, *Suevus* and *Viadrus*, which have been the cause of much confusion in the geography of ancient Germany. Indeed the mouth of the river is still called *Swinemünde*.

12. *Sp* is interchangeable with *ps*, *sk* with *ks*, and *sd* with *ds*. For the last we need only refer to the Doric use of σδ for ζ. Instances of the second interchange occur occasionally in Greek and Latin. Ϝιξος, the misletoe, is written in Latin *viscus*; εσχατος, ludicrously put down as a primitive in some lexicons, is of course only the superlative of the preposition εξ, for εξατος. The Latin *misceo* has for its participle *mixtus* as well as *mistus* (=*misctus*). The tendency to this interchange accounts too for the form *sescenti*, for *sexcenti* is never found in the best manuscripts of the best authors. But the Anglo-Saxon and English afford the most numerous instances of this metathesis. Thus the former language has the double forms *väps* or *väsp*, a wasp; *äpse* or *äspe*, tremulous (whence the name of the *aspen* tree); *häpse* or *häspe*, a lock (Grimm, 'Deutsche Grammatik,' p. 251); also *frosc* or *frox*, a frog; *fiscas* or *fixas*, a fish; *tusc* or *tux*, a tusk; *asce* or *axe*, cinder; *ascjan* or *axjan*, to ask (*ibid*, p. 256). Hence it will be seen that it is a mere accident if in our own tongue *axe* and *waps* have been rejected as vulgarisms in favour of *ask* and *wasp*. The provinces still prefer the *ks* and *ps*. Thus a Kentish countryman talks of a *whips* rather than *whisp* of hay. May we not in this way establish the identity in name of several of our rivers, as *Axe*, *Exe*, *Esk*, and *Usk*?

13. *S* is often lost. Inattention to this fact is the cause of much confusion in the grammars of the Greek language. Thus the neuter nouns in ος must once have had a corresponding σ in the genitive, γενες, γενεσος, &c., afterwards γενος, γενεος. Hence the retention of the *s* in the vocatives of proper names formed from neuter nouns of this class, as Διογενες, Δημοσθενες, Σωκρατες. (See 'Journal of Education,' vol. iv., 333.) Above all, the neglect of this letter in the original (as here assumed) forms of certain present tenses leads to apparent anomalies in the derived forms. Thus from κλει(σ)ω we should have without any irregularity κεκλεισμενος; from γευ(σ)μαι without difficulty γευσ-τικος, as well as the Latin *gus-tus*, *gus-ta-re*; from δε(σ)ω, δεσμος, in which the sibilant corresponds, as it so often does, to the guttural in *liga-re*, *dica-re*, and the English *tight* from *tie*. The Latin language in such cases changes the sibilant into an *r*; but even this language is not at all unwilling to discard an *s*, particularly at the end of words, as in the double forms *magis* and *mage*, *videris* and *videre*, *ipsus* and *ipse*, *puer* for *puerus*. Nay, even the neuters of adjectives seem to have lost the final *s* of the nominative in this way. At any rate *potis* is used for a neuter nominative as well as *pote*. The third person of the Latin perfect may possibly owe its occasional long quantity (*perrupīt*, Hor.; *subiīt*, Hor.; *rediīt*, Ovid, &c., &c.) to an older orthography ending in *ist*; for as the other perfects of the indicative as well as those of the subjunctive and infinitive of the active verb, to say nothing of all the passive perfects, are evidently formed by the addition of the tenses of the verb *esse*, so *perrupistis* and *perruperunt* contain in the two last syllables the almost unaltered forms of *estis* and *esunt*, and seem to justify the idea that *perrupit* is a corruption of *perrupist*, that is, *perrupest*. As to form, we might compare this corruption with what we know has occurred in the French subjunctive perfect, *fusse*, *fusses*, *fût*, that is, *fust*. The French language abounds in examples of the loss of the sibilant. Thus from the Latin *asinus*, *magister*, *noster*, *quadragesima*, are derived, first, *asne*, *maistre*, *nostre*, *caresme*, and then, according to the modern orthography, *âne*, *maître*, *notre*, *carême*, to say nothing of the silent *s* in such words as *mais*, *vous*, *isle*, *est*, &c.

SABADILLIC ACID, a name sometimes given to cevadic acid. [CEVADIC ACID.]

SABADILLINE (*Sabadillia*). A poisonous alkaloid, found along with jervine, colchicine, and veratrine in white hellebore. Its composition is not known.

SABAEI (Σαβαῖοι), a people of Arabia Felix, on the borders of the Red Sea, in the northern part of the modern Yemen. They are described by Diodorus and Strabo as the most numerous, and, together with the Gerrhaei, as the richest people in Arabia. Their country produced frankincense, myrrh, cinnamon, and balsam in abundance, but was also infested by deadly serpents. The inhabitants are represented as living an idle life, on account of the abundance of the produce of the country, but are at the same time said to have carried on an extensive commerce with Syria and Mesopotamia, both with the productions of their own country and also with those of Ethiopia, to which they sailed in boats made of skins.

The country of the Sabaei is mentioned in the Old Testament under the name of Sheba (שְׁבָא), and is spoken of as rich in incense, spices, precious stones, and gold (1 Kings x. 2; Jer. vi. 20; Isa. lx. 6; Ps. lxxii. 15), and as carrying on an extensive commerce with the other nations of Asia (Ezek. xxvii. 22; Job vi. 19; Joel iii. 8). The queen of Sheba who visited Solomon (1 Kings x. 1) is generally allowed to have come from this country, and not from Ethiopia, as Josephus relates ('Ant. Jud.,' viii. 6, sec. 5), who has confounded Sheba with Seba (סְבָא), which, as he tells us in another part of his work (ii. 10, sec. 2), was the ancient name of Meroe.

Korán, c. 34; Sale's *Preliminary Discourse to the Korán*, sect. 1; Edrisi, *Geographia Nubiensis*.)

SABAISM was the name given to a religious system which anciently prevailed to a great extent in Arabia and Mesopotamia. Sabaism is frequently confounded with the Sabaei, and is sometimes described as the religion of the latter people; but the two words are quite distinct, and are written differently in the Semitic languages. The first letter in Sabaism is Tsade (צ), and consequently the word would be written more correctly Tsabaism.

Tsabaism was derived, according to its followers, from Tsabi, the son or brother of Enoch, but is more probably derived from their worshipping the "Host of Heaven" (צְבָא הַשָּׁמַיִם). According to the Arabic writers, Tsabaism was the same as the religion of the ancient Chaldæans, and appears to have been one of the earliest and simplest forms of idolatry. They believed in the unity of the Deity, but at the same time paid adoration to the stars, or the angels and intelligences, which they supposed to reside in them and to govern the world under the supreme Deity. In the course of time images were made to represent the angels or intelligences dwelling in the stars; and the consequence of this would naturally be, that the common people would eventually worship them, as if they were gods. That the unity of the Deity was however still acknowledged in the religious system of the Tsabians is manifest from the way this religion is spoken of in the Korán; in which it is distinguished from polytheism, and is allowed to exist on the payment of tribute.

The religious books of Tsabaism were written in Syriac, and are referred to by early Arabic writers, but none of them are known in Europe. It appears that the Tsabians believed that the souls of wicked men would be punished for nine thousand years, and would afterwards be received to mercy. They were obliged to pray three times a day, at sunrise, noon, and sunset; and to observe three annual fasts, one of thirty days, another of nine, and a third of seven. They offered many sacrifices, but ate no part of them. They abstained from beans, garlick, and some other pulse and vegetables. They were accustomed to go on pilgrimage to Haran in Mesopotamia.

Tsabaism as a religious system no longer exists, but the name has been frequently, but incorrectly, applied to the Mandaites, or Christians of St. John, as they have been called. The name of Tsabians has been given to this sect by the Arabs, as they are accustomed to apply the term of Tsabians to many different religious sects. The Mandaites are found principally at the mouths of the Euphrates and near Bagdad, but they are not Christians, and the name of 'Christians of St. John' has been given to them in consequence of John being the name of the founder of their sect. From the manner in which John the Baptist is mentioned in the sacred books of the Mandaites, it appears that they supposed him to have been the founder of their religious system, and that his doctrines were corrupted by Christ. Their sacred books have been brought over to Europe; and an account of them is given by Silvestre de Sacy, in the 'Journal des Savans,' Paris, 1819; but they are written in such a mystical style that it is exceedingly difficult to understand their meaning. There are three books: 1. 'The Book of Adam;' 2. 'The Book of Yahya, or John the Baptist;' and 3. 'The Kholasteh,' or Ritual. They are written in a peculiar character, which bears great resemblance to the Syriac or Western Aramean; but the language in which they are composed more nearly resembles the Chaldaic or Eastern Aramean. The greater part of the 'Book of Adam' was published by Norberg, under the title of 'Codex Nasaræus, Liber Adami appellatus,' 5 vols. 4to, Lond. Goth., 1816-17. In the 'Book of Adam' the Christians, Jews, and Mohammedans are equally attacked; but the Mandaites appear to have adopted many things from Christianity, and they probably owe their origin to some of the Gnostic sects, which extensively prevailed in Asia.

SABBATH. The narrative in the book of Genesis of the creation of the world in six days is followed by these words: 'And on the seventh day God ended his work which he had made; and he rested on the seventh day from all his work which he had made. And God blessed the seventh day, and set it apart; because that in it he had rested from all his work which God created and made." (Gen. ii. 2, 3,) These words seem to imply that the seventh day is to be observed by all the rational creatures of God as a day of worship in acknowledgement of their Creator, and as a day of rest in imitation of his rest after the creation. We find no further mention of this ordinance during the patriarchal period, though some have supposed that there is a reference to it in the intervals of *seven* days observed by Noah in sending the raven and the dove out of the ark. (Gen. viii.) It is next met with at the time of the Exodus, under the name of the *Sabbath* (*שַׁבָּת, from שָׁבַת, to cease from labour*), where *rest* from labour is the peculiar character attached to the day. (Exod. xvi.) In the passage referred to, it appears to be spoken of as an institution already known, but this has been disputed. It was still more expressly enjoined upon the Jews at the giving of the law on Mount Sinai, when the reason assigned in Genesis for its institution was repeated. (Exod. xx. 8-11.) The Mosaic laws respecting the Sabbath are contained in the following passages, besides the two just quoted: Exod. xxiii. 12; xxxi. 12-17; xxxiv. 21; xxxv. 1-3; Levit. xix. 3, 30; xxiii. 3; xxvi. 2; Numb. xv. 32-36; xxviii. 9, 10; Deut. v. 12-15. It was a day of divine worship, though as to what that worship consisted in, we only know that there was to be an additional sacrifice besides the daily one, and a holy convocation of the people. This part of the institution was intended, like many others of the Mosaic laws, to keep in the remembrance of the people their allegiance to the true God, and to distinguish them from the idolatrous nations among whom they dwelt. (Exod. xxxi. 13, 17.) Its other feature was rest from labour, which was to be observed not only by every Israelite, but by resident strangers and beasts of burden. This rest had partly a religious character, as it was an acknowledgment of belief in the God who created the heavens and earth in six days, and rested on the seventh. For this reason a wilful violation of the rest of the Sabbath was punished by death, as it was an act of rebellion against God. A second object of this rest was, of course, to afford leisure for the religious services of the day; and a third was the refreshment of man and beast after the labour of the week. (Exod. xxiii. 12.) Moses does not however define the meaning of the term *work* in the Law; but it is evident from several passages in the Pentateuch that it was peculiarly all work of a servile character that was forbidden. Thus there is a special commandment to rest on the Sabbath in seed-time and harvest, as well as at other seasons (Exod. xxxiv. 21), and there were prohibitions against kindling fire (Exod. xxxv. 4) or preparing food on the Sabbath (Exod. xvi. 5, 22-30); the people were severely reprimanded by Moses for going out of their tents to gather manna (Exod. *ibid.*), and a man was put to death by the express command of God for gathering sticks on the Sabbath. (Numb. xv. 32-36.) This peculiar feature of the Jewish Sabbath was intended constantly to remind the people of their deliverance from their servile condition in the land of Egypt, as Moses states in his rehearsal of the Law, where the reason annexed to the fourth commandment in Exodus is omitted, and its place is supplied by the following words: "And remember that thou wast a servant in the land of Egypt, and that the Lord thy God brought thee out thence through a mighty hand and by a stretched-out arm; therefore the Lord thy God commanded thee to keep the Sabbath-day." (Deut. v. 15.) All bodily labour which was necessary for the service of God formed an exception to the statute. Thus the sacrifices were doubled on that day, and the animals had to be killed; the perpetual fire on the altar of burnt offering was to be supplied with wood *every* day; and a child was circumcised on the Sabbath, if that day happened to be the eighth from its birth. (Numb. xxviii. 3-10; Levit. vi. 8-13; Matt. xii. 5; John vii. 22-23.) It seems to be satisfactorily proved by Michaelis that the unwillingness to fight on the Sabbath, which we meet with in the later periods of the Jewish history, was never felt before the Babylonish captivity. The general spirit of the Jewish law concerning the Sabbath may be gathered from the following words of Isaiah (chap. lviii. 13):—"If thou restrain thy foot from the Sabbath, from doing thy pleasure on my holy day; and call the Sabbath a delight, and the holy feast of the Lord honourable; and shalt honour him (or it), not doing thine own ways, nor finding thine own pleasure, nor speaking thine own words:" then follows a promise. The Sabbath was reckoned, like the Jewish day in general, from sunset to sunset.

The Rabbins of later times added many superstitious and vexatious observances to the Mosaic law of the Sabbath, such as the prohibition of travelling further on that day than twelve miles, or, as it was afterwards settled, two thousand cubits, that is, about one mile. For further information on these points the reader is referred to Lightfoot ('Works,' ed. Pitman, Index, art. 'Sabbath').

The word *Sabbath* was also used by the Jews as a general name for their religious festivals, and also as equivalent to the word *week*. (Levit. xxiii. 15; Deut. xvi. 9; Matt. xxviii. 1; Luke xviii. 12.)

The first teachers of Christianity abolished the Sabbath, but introduced a similar institution in its place, the observance, namely, of the *first* day of the week as a day of rest and of religious worship, in commemoration of God's resting on the seventh day, and also more especially of the resurrection of Christ. Hence it was called "the Lord's day" (ἡ κυριακὴ ἡμέρα), just as the ordinance by which Christ's death was commemorated was called "the Lord's Supper." It has been held by many eminent divines that there is not sufficient evidence in the New Testament for such an institution, that the change of the day from the seventh to the first day of the week is an insuperable difficulty, that the Sabbath was a purely Jewish institution, and therefore that it is not binding upon Christians. The chief difficulties in this discussion appear to have arisen from a mistaken view of the question, as if it were, not whether the Christian church possesses *any* Sabbatical institution, but whether the *Jewish Sabbath* is binding upon Christians. The great fact of Christianity is the resurrection of Christ, which was effected by the power of the same God who created the world: this occurrence took place on the first day of the week; and to keep it in remembrance, we observe that day as our stated time of religious worship; or, as Bishop Horsley states the matter, "By keeping a Sabbath, we acknowledge a God, and declare that we are not atheists: by keeping one day in seven, we protest against idolatry, and acknowledge *that* God who in the beginning made the heavens and the earth: and by keeping our Sabbath on the first day of the week, we protest against Judaism, and acknowledge *that* God who, having made the world, sent his only begotten Son to redeem mankind."

In its very nature the Sabbath appears to be intended for the whole human race. As a religious institution, designed to keep in remembrance the God who created the world, it belongs equally to all men, since all are the creatures of the same God, and all are prone to forget every religious truth which is not continually and *regularly* forced upon their attention. As a day of rest, if needed at all (and it is generally granted that such rest is necessary), it is needed by every one who wears the human body. Its appointment is coeval with the creation of man, and long before the giving of the Jewish law. These facts seem to prove that it was intended to be perpetual, which appears also to be indicated by those words of Christ (Mark ii. 27), "The Sabbath was made for man," that is, not for the Jews merely, but for the benefit of the whole human race.

The Sabbath is used in the New Testament as a type of the eternal rest of heaven: "There remaineth a rest (or Sabbath-keeping, *σαββατισμὸς*) to the people of God." (Heb. iv. 9.) Some understand this passage of the Christian Sabbath.

(Michaelis, *On the Laws of Moses*, arts 194, 196; Lightfoot's *Works*, see the *Index*; Horsley's *Sermons*, 21, 23; Wardlaw, *On the Sabbath*; Hessey, *Bampton Lecture—Sunday: its Origin, History, and present Obligations*; Winer's *Biblisches Realwörterbuch*, art. 'Sabbath.')

SABELLIANS, an heretical Christian sect, which arose about the middle of the 3rd century. They were the followers of Sabellius, an African bishop or presbyter, who resided in the Pentapolis of Cyrenaica. They held that there was only one person in the Godhead, namely, the Father; that Christ was a mere man, but that there resided in him a certain energy proceeding from God, or a portion of the divine nature; and they likewise deemed the Holy Spirit merely a divine energy, or an emanation proceeding from God. They illustrated their doctrines by comparing God to the sun, the Word to its illuminating power, and the Holy Ghost to its warming energy. They were successfully opposed by Dionysius of Alexandria, but continued for a long time to be an important sect. (Lardner's *Credibility* and *History of Heretics*; Neander's *Kirchengeschichte*; Mosheim's *Ecclesiastical History*.)

SACBUT (*Saquebute*, Fr.) the name formerly given in England to the TROMBONE, which see.

SACCHARIC ACID ($2HO,C_{12}H_8O_{14}$). When sugar is gently heated with nitric acid of specific gravity 1·25, and the liquid subsequently boiled and evaporated, a colourless, deliquescent, sticky mass is obtained, to which the name of saccharic acid has been given. It is only slightly soluble in ether, but very soluble in alcohol or water; has a disagreeable acid taste, and has not yet been obtained in a crystalline condition.

Saccharic acid is isomeric with mucic acid. Like the latter acid, it is bibasic, forming, with bases, salts that are mostly crystalline. The neutral *saccharate of potash* contains ($2KO,C_{12}H_8O_{14}$); the acid salt having the composition ($KO,HO,C_{12}H_8O_{14}$), and occurring in acicular or oblique prismatic crystals.

SACCHARIMETRY. A generic term for certain operations undertaken with the view of ascertaining the quantity of sugar present in any matter that may contain it.

Saccharimetry is frequently performed upon solutions which are known to contain cane (ordinary) sugar only, the object being merely to ascertain the amount present. In such a case it is only necessary to take the specific gravity of the liquid by a hydrometer, and then refer to a previously prepared table of densities and per-centages. If Baumé's hydrometer be used, the degrees of specific gravity marked on its stem indicate the following centesimal proportions of sugar:—

Degrees.	Sugar per cent.	Degrees.	Sugar per cent.	Degrees.	Sugar per cent.
1	1·8	13	23·7	25	46·2
2	3·5	14	25·6	26	48·1
3	5·2	15	27·6	27	50·0
4	7·0	16	29·4	28	52·1
5	8·7	17	31·5	29	54·1
6	10·4	18	33·4	30	56·0
7	12·4	19	35·2	31	58·0
8	14·4	20	37·0	32	60·1
9	16·3	21	38·8	33	62·2
10	18·2	22	40·6	34	64·4
11	20·0	23	42·4	35	66·6
12	21·8	24	44·3		

1° Baumé corresponds to sp. gr. 1·007; 10° to sp. gr. 1·070; 20° to 1·152; 30° to 1·245; 35° to 1·299; &c.

If a liquid contain other substances besides cane-sugar, the test of specific gravity is of no value. In such a case advantage may be taken of the fact that syrup causes right-handed twisting in a ray of plane polarized light, to an extent exactly proportionate to the amount of sugar in solution. The saccharine fluid is placed in a long tube having opaque sides and transparent ends; and a ray of homogeneous light, polarized by reflection from a black glass mirror [POLARIZATION OF LIGHT], is sent through the liquid and optically examined by a plate of tourmaline, Nicol's prism, or other polarizing eye-piece. Attached to the eye-piece is a short arm which traverses a circle divided into degrees. The eye-piece and arm are previously so adjusted that when the ray is no longer visible the arm points to the zero of the scale of degrees. The saccharine solution, however, so twists the ray as to again render it visible; and the number of degrees which the eye-piece has to be rotated before the ray is once more invisible is exactly proportionate to the strength of the solution. The value of the degrees having been ascertained by direct experiment and the results tabulated, a reference to the table at once indicates the per-centage of sugar in the liquid under examination. Grape-sugar also possesses the property of dextro-rotation, but less powerfully than cane-sugar; moreover the former variety does not, like cane-sugar, suffer inversion of the direction of rotation on the addition of hydrochloric acid to its solution: an operation that furnishes data for ascertaining the amounts of cane and of grape-sugar, or of crystallisable and non-crystallisable sugar, present in a mixture. In using the polariscopo-saccharometer, it is convenient to use tubes of uniform size, and always to operate at the same temperature.

Cane-sugar is readily converted into grape-sugar by boiling for two or three hours with dilute solution of sulphuric acid, and the grape-sugar may then be estimated by the depth of colour which results on boiling it with solutions of caustic soda or potash; comparison being made with standard coloured solutions prepared from known quantities of grape-sugar. The quantity of grape-sugar, and indirectly of cane-sugar, may also be determined by the amount of its solution which is required to be added to a given volume of a standard alkaline solution of tartrate of copper and potash, before complete precipitation of the copper (as suboxide, Cu_2O) is effected. The standard solution referred to is known as Fehling's, and is thus prepared:—1 ounce of crystallised sulphate of copper, 3 ounces of bitartate of potash, 1½ ounces of pure carbonate of potash, and 14 or 16 ounces of a solution of caustic soda of sp. gr. 1·12 are mixed together, and water added until the whole measures 15,160 grains: 200 measures of this solution contain an amount of copper that is perfectly precipitated by one grain of grape-sugar ($C_{12}H_{12}O_{12}$). In using Fehling's solution, a temperature approaching the boiling point should be maintained, and the saccharine liquid should be slowly added from a graduated burette. By either of the above processes the separate amounts of cane and of grape-sugar in a mixture of the two may be ascertained by two operations; one performed before boiling with dilute acid and the other after: the quantity first indicated will be the grape-sugar, and that, being subtracted from the numbers obtained in the second experiment, gives the proportion of cane-sugar. One-eighteenth of the latter number must, however, be deducted; the equivalent of grape-sugar being higher by that amount than cane-sugar.

SACCHAROMETER, an instrument used principally in the operations of brewing, and making sugar. It serves to indicate the density of the liquid extracted from malt, or the degrees to which the juice expressed from the sugar-cane is concentrated previously to undergoing the process of crystallization. An instrument of the like kind, called a *lactometer*, is employed to exhibit the density of milk. Both of them are formed on the same principle as the hydrometer [HYDROMETER], and such instruments are sometimes comprehended under the word *aræometer*, or *gravimeter*. Their general use is to determine, when extreme accuracy is not required, the specific gravities of liquids which are of greater density than water, and even those of solid bodies in small quantities. [SPECIFIC GRAVITY.]

SACCHULMIN, the brown substance produced by the action of sulphuric acid upon sugar.

SACER MORBUS (Ἱερὰ Νόσος), a term applied apparently by the ancients to more than one disease, as Athenæus ('Deipnosoph.,' lib. vii. § 33, p. 289) speaks of *τὰς ἱερὰς καλουμένας νόσους*, and Heraclitus is said by Diogenes Laertius ('De Vit. Philosoph.,' lib. ix., cap. i., § 6 and 7) to have called Arrogance by that name: *τήν τε οἴησιν ἱερὰν νόσον ἔλεγε*. Generally however it is merely used as one of the numerous names of epilepsy [EPILEPSY], and this is the explanation given by Hesychius and Suidas *in voc.* It is first used by the author of the treatise Περὶ Ἱερῆς Νόσου, 'De Morbo Sacro,' which is published among the works of Hippocrates (tom. i., p. 587, ed. Kühn), though it was probably written by one of his successors in the Dogmatic school. (See Gruner, 'Censura Libr. Hippocr.,' Vratislav., 1772, 8vo., § 44, p. 162; and Ackermann, 'Hist. Liter. Hippocr., ap. Fabricii Biblioth. Gr.,' ed. Harles, and Kühn's 'Hippocr.,' tom. i.) The term is also found in Aretæus ('De Caus. et Sign. Diuturn. Morb.,' lib. 1., cap. 4). Theophanes Nonnus ('Epit. de Curat. Morb.,' cap. 36), Artemidorus ('Oneirocrit.,' lib. ii., cap. 12, where see Reiff's note 35), and others. The meaning of the term is obscure and uncertain, and several derivations of it are mentioned by Aretæus (*loco cit.*): "There is," says he, in Dr. Reynolds's translation, "a sort of ignominy too in the character of epilepsy, for it seems to attack those who offend the moon, and hence the disease is termed 'sacred;' or it may be from other reasons, either from its magnitude (for what is great is 'sacred'), or from the cure not being in the power of man but of God, or from the notion that a demon has entered the patient, or from all put together, that it has been so called." The author of a treatise 'De Morbo Sacro,' seems to have considered the origin of the term to have arisen from the belief either that this disease proceeds more immediately from the anger of the gods, or that it is more wonderful than others, or that its cure depends more entirely upon divine assistance; as he refutes all these opinions at some length. (See also Galen, 'Comment.' vi., in Hippocr. 'Epidem.,' lib. vi., tom. xvii. B., p. 341, ed. Kühn.) The other reason that is given, namely, "the magnitude of the disease," is supported by the author of the 'Schol. MS. in Gregor. Nazianz. in Bastii Excerptis,' quoted in Gaisford's Suidas: *τινὲς ἱερὰν ἑτέραν τινὰ λέγουσι νόσον τῷ ὀνόματι τούτῳ, τὴν ἐπιληπτικὴν οἶμαι· ἱερὰ δὲ αὕτη κυριώτερον ἂν κληθείη, διαφέρουσα πασῶν τῇ κακώσει· ἐπεὶ καὶ μέγα τὸ ἱερὸν τοῖς γλωσσηματικοῖς εἴθισται καλεῖσθαι.* It is also indirectly supported by the analogous expressions *ἱερὸν μένος Ἀλκινόοιο* (Homer, 'Odyss.,' lib. vii., v. 167), *ἱερὸς ἰχθύς* (see Athenæus, 'Deipnosoph.,' lib. vii., § 17-20, pp. 282-4), and especially by the anatomical name *ἱερὸν ὀστοῦν*, "os sacrum," of which this seems to be the most probable interpretation. Cælius Aurelianus gives the following interpretations: "Appellatur Epilepsia '*sacra* passio,' sive quod divinitus putetur immissa; sive quod sacram contaminet animam [which is supported by Apuleius, 'Apolog.,' p. 58, ed. Prisc.]; sive quod in capite fiat, quod multorum philosophorum judicio sacrum templum est partis animæ in corpore natæ [which is the reason given by Theophanes Nonnus, *loco cit.*]; sive ob magnitudinem passionis, majora enim vulgus *sacra* vocavit." ('De Morb. Chron.,' lib. i., cap. 4. p. 291, ed. Amman.) Of all the explanations that have been proposed, perhaps that which derives the term from the disease being supposed to be under the more immediate direction of the gods is the most likely to be the true one, both as being the most ancient and also as being that which Galen preferred: it is also indirectly confirmed by two popular names mentioned by Leo in his 'Synopsis Medicinæ, lib. ii., cap. 2 (ap. Ermerins, 'Anecd. Med. Gr.,' Lugd. Bat., 8vo., 1840), namely, *δαίμων* and *σεληνιασμός*. If this is not the real meaning of the term, it must have been applied "*ob magnitudinem passionis*," for none of the other derivations bear the slightest marks of probability.

SACK, a Spanish wine of the dry kind; in French, *Vin sec.* It is the same wine which is now named Sherry. Falstaff calls it *Sherris sack*, that is, sack from Xeres in Spain. Ritson supposed that the old sack of Falstaff's time was a compound of sherry, cider, and sugar; but he produced no good authority for the assertion. The chief difficulty about sack has arisen from the later importation of sweet wines from Malaga, the Canaries, &c., which were at first called Malaga, or Canary sacks; sack being by that time considered as a name applicable to all sweet wines. One of these sweet wines still retains the name of sack. It is little used, but being proverbial for sweetness, it has caused some misunderstanding as to the original dry sack.

SACRAMENTS and TRANSUBSTANTIATION. The Christian Sacraments are not merely certain high forms, but the highest acts of church membership. For the Christian Church being but the outward visible representation of the internal fellowship of the faithful with Christ, and with one another; this twofold element of the church is most fitly corresponded to by the institution of external visible actions, intended to express an internal spiritual effect or grace. Such are the Sacraments, a term used to express "Sacramentum," by which the Greek *mysterion* is rendered in the old Italic versions, and also in the Vulgate.

With regard to the number of the Sacraments, as is well known, two opinions are current among Christian communities,—the Greek and Romish Churches holding the number of seven, while all other Catholic bodies limit the number to two. The history of this difference may be briefly stated as follows. The term Sacrament was applied by the Fathers to the mysterious doctrines of religion, as the Trinity, the Incarnation, and, in some instances, to the ordinances of religion in a wide sense. In a certain sense the seven-fold system of the Church of Rome may be considered as an abatement of the lax terminology of some of the Fathers. The title of sacraments is by her limited to seven actions—baptism, or the sign of our spiritual birth; the eucharist, in which our spiritual life is nourished; confirmation, for the strengthening of the same; penance, for the restoration of the lapsed; extreme unction, as a preparation for death; matrimony, for maintenance of the race of mankind in general; and orders, for that of the race of God's ministers.

Without entering into the controversy on this subject, it will be sufficient to observe that the number of seven, as asserted by the Church of Rome, is very far from being sanctioned by the uniform ascent of ecclesiastical practice. Antecedently to a very modern synod (that of Florence) the number of seven had never been positively settled.

The two sacraments then, to which, in the judgment of all Catholic bodies (save the Greek and Romish communions) the number is properly limited, are those of baptism and the Lord's supper. It is asserted that on the basis of two Jewish rites of recognised typical import our Lord established, by direct command, those two sacraments, of which alone the authority is unquestionable. An indirect argument in favour of this more restricted view may be drawn from the Romanist statements respecting the relative value of the several sacraments. For although the authorities of that church are consistently anxious to prove the entire number of seven to be equal in rank, the dignity which they directly attribute to the eucharist, and that which they cannot withhold from baptism, may be in some sort alleged as an involuntary assent to the doctrine of the opposite party.

The principal feature of the scheme of salvation providentially offered to man is faith in the Saviour; that is, that through Christ a path is opened to heaven. The eye of this Christian faith is not confined exclusively to the doctrine, or the person, or the sufferings and death of Christ; but it comprises within its range the entire system. It consists in a perfect devotion to Jesus; in an internal union with him, and spiritual imitation of him, in which man appears as a new creature, alike as regards knowledge, feeling, and action. The symbols of this faith, and the acts by which an obligation to it is expressed, are the two Christian sacraments—baptism and the Lord's Supper. Baptism will be found fully treated under that head.

The various opinions respecting the exact import and appropriate benefits of the Lord's Supper are of high antiquity. A history of these will be found in the article COMMUNION. The difficulties connected with the question are increased by the general adherence to the words of Scripture, observable in the liturgical formularies. The non-existence of a dogmatical theology during the first ages of the Church is well known, which renders it unnecessary to look for exact scientific definitions throughout that period. But, concurrently with the uniformity of practice, there is to be found a three-fold variety of interpretation, corresponding with the peculiar views of what may be considered the three principal schools of early Christian theology.

The Church of Asia Minor, as also some great Origenists in the West, professed views of the holy eucharist which the Church of Rome and the Lutheran have (to a certain extent,) pleaded as the sentiments of antiquity supporting their own. Such were those of Ignatius, Justin Martyr, Irenæus, Hilary of Poitiers, Cyril of Jerusalem, Gregory of Nyssa, Ambrose, Chrysostom, and Theodoret. The common point of agreement among these writers is the communion of the body and blood of Christ in a high spiritual sense *generally*. But a considerable difference of statement regarding details is observable among them. For example, some expressions of Cyril of Jerusalem are directly and strongly opposed to the tenet of transubstantiation, which Gregory of Nyssa is not unfairly quoted as supporting.

The views of the Church of North Africa, as expressed by Tertullian, Cyprian, and Augustine, differed as a whole from those just named. The African doctors may be considered as regarding the eucharist as an active and efficacious symbol.

A third party, that of the school of Alexandria, applied in some measure its usual allegorising views to this sacrament. But even in the absence of all approach on the part of these Fathers to corporeal views, a leaning to the sentiments of the first-mentioned party is observable in some portions of their writings.

Each of the many designations by which this sacrament was known until the close of the 4th century, bore some reference to the original object of its institution. This may be traced throughout the various expressions—breaking of bread, communion, Lord's supper, eucharist, oblation, commemoration, and passover. Ecclesiastical antiquity cannot be adduced with fairness in support of the literal interpretation applied by a large body of Christians to the words used by our Lord in His institution of the sacrament. John of Damascus, the principal writer of the Eastern Church, maintained (it is true), on the authority of some of the Fathers, a literal change of the bread and wine into the body and blood of Christ. The figurative interpretation put upon the words of Christ by a council at Constantinople in A.D. 754 was denied at the second council of Nice in 787, when it was ruled that the sacred symbols are not figures or images at all, but the real body and blood. Theophylact and Euthymius Zigabenus coincide with John of Damascus. But it was reserved for the Western Church to carry out into its remote consequences the doctrine of a material change, which, in common with her Eastern sister, she ultimately came to maintain. This doctrine was maintained during the 9th century by Paschasius Radbert more precisely and authoritatively than before. He was opposed, however, by Rabanus Maurus, and Ratramn or Bertram (whose sounder and more scriptural views many centuries later found an echo in our own Ridley), and also by the suspected ingenuity of Scotus Erigena.

Various instances of opposition to the doctrine of transubstantiation subsequently occurred; but, supported by authority like that of Sylvester II. (the famous Gerbert), it continued to gain ground. During the 11th century it had become an article, to dissent from which was heretical; although a doctrine substantially the same with that held by the Anglican Church at the present day was preached by doctors such as Alfric, and although an archbishop of Sens, Leutheric, advocated opinions regarding the eucharist similar to those which involved Berengar of Tours in controversy with Lanfranc, and drew upon him the hostility and condemnation of popes and councils.

Among the numerous controversies connected with the different theories on the subject, the more modern opinions are marked by a tendency to regard the eucharist as a purely symbolical rite. For transubstantiation Luther substituted a corporal local presence, commonly called consubstantiation. There appears an inconsistency in the obstinacy with which Luther contended for his theory. He had abandoned the sacrifice of the mass and the theurgic pretensions connected with the real presence which made this dogma of such importance to the Church of Rome. Luther's great object was to preserve this sacrament from being degraded by the same unspiritual *subjective* views (as he conceived) with which it was menaced by Carlstadt and his party. This evil would be best remedied by a bold assertion of the *objective* dignity of this sacrament, divested of the superstitious additions with which it was encumbered in the Church of Rome. Hence the Lutheran doctrine of the eucharist. What has been said will suffice to show how ungrounded is the charge sometimes brought against Luther—that he threw away the substance while he retained the shell. But his tenacious adherence to scholasticism in this respect contrasts strangely with his uncompromising hostility to that philosophy respecting the fundamental dogma of justification by faith. Zwingli, on the other hand, together with a corporal and local presence, rejected all notion of a spiritual presence and graces. But the opinions of Calvin shortly afterwards superseded the colder ones of Zwingli, many of whose followers, to quote from Waterland, abandoned the "notion of naked signs and figures to the Anabaptists of those times, where they rested, till again revived by the Socinians, who afterwards handed them down to the Remonstrants."

The point of divergence between the adherents of Luther and Calvin respecting the eucharist may be stated thus:—The former party held, according to the earlier Augsburg Confession and the Form of Concord, that the body of Christ was contained in, with, and under, the sacramental bread. The others held the doctrine only of a real spiritual feeding on the body of Christ, which took place in the faithful contemporaneously with the reception of the outward elements. In the opinion of Waterland, "Calvin refined upon Zwingli's scheme, steering a kind of middle course between the extremes. He appears to have set out right, taking his ground with good judgment; and had he but built as carefully upon it afterwards, no fault could have been justly found."

Bishop Lloyd considered that the Anglican doctrine was borrowed from that of Calvin. The third and fourth clauses of the twenty-eighth article, respecting the manner and means after and by which the body of Christ is taken in that sacrament, would seem to support this view. But the words of Waterland may be fairly quoted as expressing briefly the opinion held by the majority of Anglican teachers on this subject: "Our divines who came after Calvin had some advantage in point of time, and a greater still in the rule or method which they pitched upon as most proper to proceed by. The sum of all is, that sacramental or symbolical feeding in the eucharist is feeding upon the body broken and the blood shed under the signs and symbols of bread and wine; the result of such feeding is the strengthening or perfecting our mystical union with the body glorified, and so, properly speaking, we feed upon the body as dead, and we receive it into closer union as living, and both in the eucharist when duly celebrated."

SACRIFICE, an offering made to God, in which the thing offered is wholly or partially destroyed. It is generally supposed that sacrifices were instituted immediately after the fall of Adam, when God made with him what is called "the covenant of grace;" and that on this occasion the sacrifice was partly an atonement for Adam's sin, partly a ratification of the covenant. This supposition is founded on the fact that God clad Adam and Eve with the skins of beasts; and since animal food had not yet been given to man, it is thought that these beasts must have been slain as sacrifices. (Genesis, chap. iii.) In the next generation we meet with sacrifices as a divine appointment. (Gen. iv. 1–5.) All over the world sacrifices have been found in some form or other, which is another proof of their great antiquity. Their chief object is to atone for sin [Atonement]; but they have also been offered as the means of gaining the favour and assistance of God, and of expressing submission and gratitude to him. They may be divided into two classes, bloody and unbloody. In the heathen world human sacrifices have been very generally prevalent, apparently from a notion that human life is the most precious thing that can be offered to the divine Being. Sacrifices form a large part of the Jewish law. Christians believe them to be abolished since the death of Christ, since, as Paul argues in his Epistle to the Hebrews, that was the one great sacrifice which has for ever made atonement for the sins of men.

SACRILEGE is "the felonious taking of any goods out of any parish-church or other church or chapel." By the common law it was a capital offence, though the offender seems to have been entitled to the benefit of clergy at the discretion of the ordinary. But even if it were not clergyable at the common law, yet the statute 25 Edw. III. c. 4, "De Clero," comprehended this as well as other crimes, and gave "the privilege of holy church to all manner of clerks, as well secular as religious." Afterwards, by the statutes of 23 Hen. VIII., c. 1, and 25 Hen. VIII., c. 3, revived by 5 & 6 Edw. VI., c. 10, all persons not in holy orders were excluded from the benefit of clergy who on an indictment for *robbing* any church, chapel, or other holy place were convicted, stood mute, or peremptorily challenged more than twenty of the jurors; and by 3 & 4 Will. & Mary, c. 9, the same consequences followed upon their outlawry. It seems, however, that no sacrilege came within these statutes which was not accompanied by an actual *breaking* of a church, &c. But by 1 Edw. VI., c. 12, all persons in general were deprived of their clergy for the felonious taking of any goods out of any parish-church or other church or chapel in all cases, except that of challenging more than twenty jurors: and by 3 & 4 Will. & Mary, c. 9, upon such a challenging, as well as upon conviction, &c., upon an indictment, whether in the same county wherein the sacrilege was committed, or in a different one. It seems that sacrilege was the only felony at common law which deprived the offender of the privilege of sanctuary.

The present state of the law of sacrilege depends on the statute 7 & 8 Geo. IV., c. 29, s. 10, which enacts that "if any person shall break and enter any church or chapel, and steal therein any chattel, or having stolen any chattel in any church or chapel, shall break out of the same, every such offender, being convicted thereof, shall suffer death as a felon."

By 9 Geo. IV., c. 55, s. 10, the same protection was extended to meeting-houses and all places of divine worship.

By the statute 5 & 6 Will. IV., c. 81, the punishment of death was abolished, and transportation for life or for any term not less than seven years, or imprisonment with or without hard labour for any term not exceeding four years, was substituted in its place. These penalties were again altered by 6 Will. IV., c. 4, which limited the term of imprisonment to three years, and gave to the court a discretionary power of awarding any period of solitary confinement during such term. But now, by the statute 7 Will. IV. and 1 Vic. c. 90, s. 5, no offender may be kept in solitary confinement for more than one month at a time, or three months in the space of one year. And see 16 & 17 Vict. c. 99.

SADDLERY. [Leather Manufacture.]

SADDUCEES (Σαδδουκαῖοι), one of the four Jewish sects at the time of Christ. The Rabbinical tradition makes them the followers of Sadoc, a disciple of Antigonus Sochos. They denied the existence of any spiritual beings except God, and believed that the soul died with the body, and therefore that there was no resurrection. (Matt. xxii. 23; Acts, xxiii. 8.) In consequence of this disbelief in a future state of rewards and punishments, they were inexorable in punishing crimes. They rejected the doctrines of predestination and providence, maintaining that men were left to determine their own course without assistance or hindrance from God. They rejected the traditions of the Pharisees, and adhered to the text of the Mosaic law. They have been accused of rejecting all the books of the Old Testament except the Pentateuch; but the passage of Josephus, on which this charge is founded, does not sustain it. Though inveterately opposed to the Pharisees, they united with them against Christ. During the period to which the New Testament refers, though less numerous and less popular than the Pharisees, they seem to have been superior by the eminent men they had in the Sanhedrim, and some of their body were high-priests, as Caiaphas and Ananias. It seems that they considerably modified their opinions in progress of time, and received the doctrines of angelic beings and of the resurrection; so that at last they were only distinguished by their rejection of tradition, from which circumstance they obtained the name of Caraites, in the 8th century A.D. (Josephus, 'Antiq.,' xiii. 5, 6, 9, 10; xviii. 1, 4; Jahn's 'Biblical Antiquities; Winer's 'Biblisches Realwörterbuch.')

SAFES. [Fireproof Construction; Fireproofing.]

SAFETY LAMP. [Lamp, Safety.]

SAFETY-VALVE. An opening in a steam-boiler loaded with a certain weight, which is raised by the steam when the latter acquires a certain elasticity, so that a portion of the steam escaping relieves the boiler from internal pressure and danger of bursting. In the locomotive engine the boiler is furnished with two loaded valves, one of which is beyond the engine-man's control, and is called the *lock-up valve*, while the other, at a somewhat lower pressure, can be regulated by him, by means of a lever and spring balance. By making the aperture large enough, the whole of the steam can be let off as soon as it is generated, by which means the engine is put out of work. The valve may be loaded by means of a weight placed upon it, or by means of a lever with an adjustable weight according to the pressure required.

SAFFLOWER, or *Bastard Saffron*, is noticed under the botanical name of the plant [Carthamus *tinctorius*, in Nat. Hist. Div.] yielding it. This plant has been cultivated in Eastern countries from the earliest times, both on account of the oil expressed from its seeds and for the colouring matter procurable from its flowers, which in their dried state form the safflower of commerce. The oil of the seeds of carthamus was valued by the ancients as a laxative medicine, and is still employed by the Asiatics for the same purpose, as well as for external application. It is most extensively used as a lamp-oil. The seeds are eaten by some birds, especially parrots, whence they are called "graines de perroquets." The plant is, however, chiefly cultivated on account of its flowers, not only in China, India, and Egypt, but also in the south of Europe. That from China is the most valued, and the Bengal safflower considered the most inferior. This might be remedied probably by selecting and sowing only the seed of the most highly coloured flowers, and then adopting the Chinese method of gathering the crop when the flower is in the highest perfection, and only picking off the upper and coloured parts of the floret, instead of the whole floret, of which the lower part is whitish-coloured. Besides this, careful drying is essential to the preservation of the colour, or, as Mr. E. Selly has recommended, gradual drying "in close chambers with some organic substance, or perhaps with hot sand;" but the natural heat of the climate in darkened chambers would probably be sufficient.

SAFFRON consists of the dried stigmas of the *Crocus sativus*, a plant native of Greece and Asia Minor, but extensively cultivated in Austria, France, Spain, and also formerly in England. The Sicilian saffron is said to be the produce of the *Crocus odorus*, but both in ancient and modern times this sort has been little esteemed. England is chiefly supplied from France and Spain; that of Spain being preferred. In Germany, however, Spanish saffron is not in such repute as the Austrian, great pains being taken in the cultivation of the plant in that country. The cormi or stems are subject to the attacks of a fungus, *Sclerotium Crocorum*, by which they are extensively destroyed. When the flowers expand, and are thoroughly open under the influence of the sun, the stigmas, of which there are three, are plucked out, a portion of the style remaining attached to them, and spread upon paper, to be dried either by means of portable kilns over which a hair-cloth or fine sieve is stretched, or in a room by the sun. The stigmas are from an inch to an inch and a half long, narrow and roundish where they are attached to the style, but spreading out and club-shaped towards the apex, which is truncate. The upper part is of an orange or brownish red; the part of the style termed feminelle is yellowish. The stigmas have a penetrating, aromatic, and, when in large quantity, stupefying odour, and a bitter aromatic taste; by mastication the mouth and saliva are rendered yellow. By long internal use of them many of the secretions acquire a yellow colour. The stigmas of *Crocus Pallasii*, *C. longiflorus*, and *C. Serotinus*, are not so long as those of the genuine saffron crocus, and are altogether devoid of the strong odour. They and many other articles, such as the florets of the safflower (*Carthamus tinctorius*), those of the marigold (*Calendula officinalis*), slices of the flowers of the *Punica granatum*, and pieces of dried flesh, are used to adulterate the true saffron. The saffron of English commerce is generally very pure; but the high price offers much temptation to sophistication, which might be diminished by collecting the stigmas of the *Crocus vernus*, which are little inferior in colour or potency to those of the autumnal crocus. According to Mr. Pereira, one grain of good saffron contains the stigmata and styles of nine flowers; hence 4820 flowers are required to yield one ounce of saffron. Saffron was formerly met with in two forms, *hay saffron* and *cake saffron*, the former is now alone in demand, the latter being entirely an artificial compound of the florets of the safflower, gum, and some other materials. Genuine saffron is often moistened with oil, which gives an appearance of freshness to old and dry saffron; but the mixture is easily detected. Saffron consists of a volatile oil, in variable proportion, which is heavier than water, of polychroite, which is a compound of a volatile oil and a bitter red substance (or polychroite properly so called), gum, and other principles. [SAFRANIN.]

Saffron had formerly many powerful and important properties mistakenly assigned to it. On the Continent it is much used as a condiment with food. In England it is used in medicine, chiefly as a colouring principle. It is also employed as a pigment for water colours, and as a dye, for which purpose considerable quantities are imported from France.

SAFRANIN. (*Polychroite.*) Alcohol takes up from the aqueous extract of saffron a peculiar colouring matter to which these names have been given. On the evaporation of the alcohol it forms an uncrystallisable mass, very soluble in water and alcohol, but almost insoluble in ether and in oils. Its composition has not been ascertained.

SAGAPENUM, said by Willdenow to be yielded by *Ferula Persica* which no one regards as certain, though it is generally believed to be furnished by some species of Ferula. The plant (or plants) which yield it grow in Persia and other regions of the East. It is procured in the same way as assafœtida. It occurs either in tears or irregular masses, of a dirty brownish colour, containing in the interior white or yellowish grains. It is difficult to break (unless when very old), is tenacious, and not easily powdered, except in winter. It has the same alliaceous odour, but less powerful, as assafœtida, with a nauseously bitter, acrid, guttural taste.

It consists of, in the 100 parts, according to Pelletier :—

Resin	54·26
Gum	31·94
Bassoria	1·0
Peculiar substance	0·60
Acidulous malate of lime	0·40
Volatile oil, including loss	11·80
	——100·

Brandes found only 3·73 per cent. of volatile oil, and less resin than in the above; and Geiger says it has less volatile oil than assafœtida; while Pelletier's analysis gives nearly three times as much. The resin, by the action of hot hydrochloric acid, becomes first reddish, then blue, and at last brown. The resin appears to be a mixture of two kinds, one soluble, the other insoluble, in ether. Formerly there were two kinds of Sagapenum in commerce, but at present only the worst of the two is met with. It is said to be adulterated with assafœtida and bdellium. Its action on the human system is the same as that of assafœtida and other fetid gum-resins. [ASAFŒTIDA.]

SAGITTA (the Arrow). This constellation is one of the old ones, and is situated over the back of AQUILA. In CONSTELLATION it is stated that Sagitta is a part of Aquila in Aratus; but this, though very commonly stated, is erroneous, as is noticed by Grotius in his notes on Aratus; though the edition of Grotius himself countenances the error in the plates. Grotius traces the mistake to Germanicus in his Latin version.

The principal stars are as follows :—

Character.	No. in Catalogue of Flamsteed.	No. in Catalogue of British Association.	Magnitude.
α	5	6739	4
β	6		4
γ	12	6858	4

SAGITTARIUS (the Archer), one of the constellations of the zodiac, the figure of which is that of a centaur drawing the bow, and situated below Aquila, between Scorpius and Capricornus: it must not be confounded with CENTAURUS. The mythological account of this constellation is very meagre, and confirmatory of the reason given in CONSTELLATION why the Greeks could not have been the first to give names to the constellations. Hyginus can find no more illustrious mortal to fix in this part of the heavens than one Crotus, the son of Eupheme, the nurse of the Muses; but it is worth noting that he says many (in his time) denied that the original figure was that of a centaur.

The principal stars are as follows :—

Character.	No. in Catalogue of Flamsteed (Piazzi)	No. in Catalogue of British Association.	Magnitude.
γ^2	10	6115	3
μ	13	6168	4
δ	19	6209	3
ε	20	6233	3
λ	22	6263	4
ξ^2	37	6461	4
ζ	38	6489	3
ο	39	6507	4
τ	40	6521	4
π	41	6548	4
β^1	(54)	6608	4

SAGO, a word signifying, in the language of the Papuas, *bread*, since it constitutes the staple article of food of the inhabitants of the Eastern Archipelago and other parts where the plants which yield it grow. It is not a seed, as sometimes supposed, but the farina from the stem of several palms and palm-like vegetables. The old stems of *Caryota urens* also yield goods ago. Sago is a variety of starch, prepared by the plant for the use of the flowers and fruit, and is most abundant just before the evolution or appearance of the spadix or flower-bud, which is known by a whitish dust transuding through and covering the leaves. At this time the stem is cut down, near the base, and then divided into pieces of five or six feet in length. "A part of the outer hard wood is then sliced off, and the workman, coming to the pith, cuts across the longitudinal fibres and the pith together, leaving a part at each end uncut, so that when it is excavated there remains a trough, into which the pulp is again put, mixed with water, and beaten with a piece of wood; the fibres, being then separated from the pulp, float at the top, and the flour subsides. After being cleared in this manner by several waters, the pulp is put into cylindrical baskets made of the leaves of the tree; and, if it is to be kept some time, those baskets are generally sunk in fresh water to keep it moist, for the pulp will keep long if preserved from the air, but if exposed it presently turns sour." (Forrest's 'Voyage to the Moluccas.')

The quantity yielded by one tree is prodigious. Five or six hundred pounds are not an unusual produce for one tree; and as the vegetation still remains after being felled, a stem again springs up, which goes through the different stages of growth till it is fit for the axe.

The flour or powder is rarely imported, granulated sago being the state in which it is commonly brought to Europe. To bring it into this state from the flour, it must be moistened and passed through a sieve into an iron pot (very shallow) held over a fire, which enables it to assume a globular form. Thus all our grained sago is half baked, and will keep long. Of this granulated sago there are two varieties, the common or brown sago, and pearl sago. The latter is in small, hard, horny, or semi-transparent grains, about the size of a pin's head; the former are in large grains, about the size of the grains of pearl barley. Both are inodorous, and have an insipid taste. They swell in cold water, and are nearly thoroughly soluble in boiling water, so as to form a thick starch-like solution, which may be used as a pudding, or prepared in other ways as an article of diet for children and invalids, if a farinaceous diet is required. Care must be taken to distinguish a factitious sago prepared from potatoes. This can only be done by the microscope.

SAIL, a quantity of canvas attached to the yards or stays of a boat or ship in order to receive the impulse of the wind, and thus give motion to the vessel. The depth of a sail is capable of being diminished at pleasure, according to the force of the wind, by means of the reef-points.

The principal sails of large vessels can be placed at right angles to the direction of the keel of the ship, and this position is given to them when the vessel goes before the wind; in other cases the same sails may, by means of the braces, be placed obliquely to the keel. The sails which are attached to the ship's stays, and the sails of boats or small vessels, are generally in a vertical plane passing through the keel; a certain degree of obliquity to that plane may, however, be given to them at their lower extremities if necessary. Sails are strengthened by ropes, called bolt-ropes, sewn along their edges in order to prevent them from being easily torn by the action of the wind.

When a vessel is in still water, the pressure of the wind against the sails overcomes its inertia, and motion takes place in some direction. The motion goes on increasing by the accelerative power of the wind; but at the end of a certain time the resistance in an opposite direction, both of the air against the sails and hull of the ship, and of the water against the latter, becoming equal to the accelerative power of the wind, the ship acquires a terminal or uniform velocity, and in this state (neglecting the resistance of the air) there may be said to be an equilibrium between the pressure of the wind against the sails and of the water against the vessel.

The principal problem connected with the motion of vessels on the water has for its object the determination of the relation between the velocities of the wind and of the vessel; and its solution consists in finding algebraic expressions for those pressures, and making them equal to one another. But many practical difficulties present themselves in investigating that relation; for the pressure of the wind is modified by the form which the sail assumes when acted upon, by the obliquity of the wind's direction to the general plane of the sail, and by the interference of one sail with another, by which interference the wind may be partly intercepted, or currents may be produced in directions different from the general direction of the wind. The resistance of the water is also greatly modified by the form of the ship's hull, and by the direction of its motion with respect to the line of the keel. These difficulties cannot be removed; therefore the results of mathematical researches concerning the motion of ships can only be considered as very remote approximations to the rules which should guide the practice of the seaman. And in order to simplify the problem, it is necessary to suppose that the ship is furnished with only one sail, whose area is such that the action of the wind upon it may be equivalent to the efficient action of the wind upon all the sails. The *centre vélique*, as it is called by foreign writers, or the centre of pressure or *effort*, must also be supposed to be at the centre of gravity of the sail. That part of the ship's surface which is resisted by the water must moreover be represented by a plane surface whose area is such that this resistance shall be equivalent to the efficient action of the water on the ship.

The pressure of the air perpendicularly against a plane surface equal to one square foot is usually estimated at [illegible] lb. avoirdupois, the surface pressed being at rest, and the wind moving with a velocity equal to one foot per second, or about 0·68 mile per hour; also the resistance of water against a like surface and moving with an equal velocity is estimated at 1·5lb. The pressure or resistance, by the laws of hydrodynamics, varies with the square of the velocity; and, from the resolution of forces, it may be shown [AERODYNAMICS] that the effective force with which a fluid strikes a plane surface obliquely, when estimated in a direction perpendicular to the plane, varies with the square of the sine of the inclination to the plane. This, however, is only an approximation for practical purposes, its insufficiency arising from want of allowance for the accumulation of force depending on the shape or curved surface of the sail; and, from the experiments of Bossut, D'Alembert, and Condorcet, it appears to hold good only for inclinations between 50° and 90°. The experiments of Smeaton indicate that the pressures vary nearly with the sine of the inclination, when the latter is between 50° and 60°; at greater inclinations the pressure is some fractional power of the sine, and at very small inclinations it approaches nearly to the square. But the following formula of Smeaton gives the effective velocity very nearly as

$$= \text{V} \sin\theta^{1\cdot842 \cos.}$$

From the experiments of Dr. Hutton it is found that at inclinations between 50° and 90° the pressures vary nearly as the sines of the inclinations.

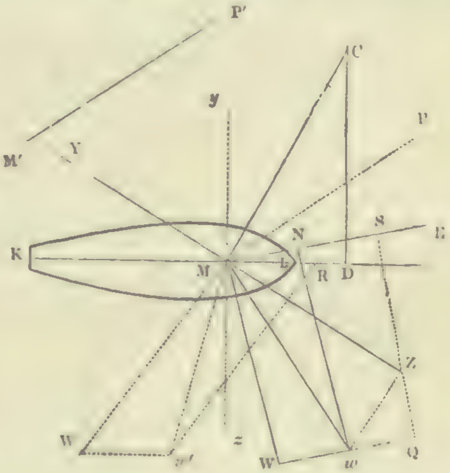
In determining the pressure of a fluid against the surface, which is in motion, it must be observed that, by the laws of the collision of bodies, the efficient velocity of impulse is to be expressed not by the absolute, but by the relative velocity of the impelling power. Hence, when the wind and ship are moving in the same direction, the effective velocity is the difference, and when they are moving in opposite directions, it is the sum of their several velocities. It must also be observed that the force of the wind and the reaction of the water are to be considered as taking place in horizontal directions, and that the effective pressure of the wind on a flat sail is in a direction perpendicular to the plane of the sail, whatever be the position of the latter and the direction of the wind.

Now when a ship sails before the wind in still water, if we consider the sail as a plane surface at right angles to the keel of the ship and to the direction of the wind; representing the pressure of the air on a square foot, when the velocity is one foot per second, by P, and the pressure of the water on a square foot with an equal velocity by P'; also putting V for the velocity of the wind, and V' for that of the ship, both being expressed in feet per second; A for the area of the sail, and A' for that of a vertical section through the immersed part of the ship taken perpendicularly to the keel; the equation of equilibrium will evidently be

$$\text{A}.\,\text{P}.\,(\text{V}-\text{V}')^2 = \text{A}'.\,\text{P}'.\,\text{V}'^2;$$

and from this equation V' may be easily found. It follows from the same equation that, when the other terms are constant, $\dfrac{\text{V}'}{\text{V}-\text{V}'}$ varies with $\sqrt{\text{A}}$, or the velocity of the wind in the sail is to the velocity of the ship as unity is to the square root of the surface of the sail.

But while the plane of the sail is supposed to be perpendicular to the keel of the ship, let the direction of the wind be oblique to both, and let the force of impulse perpendicularly to the sail be proportional to the square of the sine of the inclination of the wind to the sail; then, if K L be the keel, M the place of the mast, $y\,z$ the position of the yard, and $\text{W}'\text{M}$ represent the direction and velocity of the wind, we shall have $\text{W}'\text{M}.^2 \sin.^2 \text{W}'\text{M}z$ for the force of impulse with which a particle of air acts on the sail. This value of the impulse is, however, correct only at the moment before the ship begins to move; for, let the ship be advancing in the direction K L with a velocity such that the sail moves parallel to itself from M to R, while a particle of air would move from W' to M if the ship were at rest,—it will be evident now that a flag at M, which, when the ship is at rest, would have its plane in the direction $\text{W}'\text{M}$ produced, being carried by the motion of the ship from M towards L, would be acted on by the particles of air coming against it, as if it were resisted by forces parallel to M R and tending from R towards M; therefore the forces parallel to $\text{W}'\text{M}$ and R M being respectively proportional to those lines, the flag will by the composition of forces take the direction $w'\text{M}$, the diagonal of the parallelogram $\text{W}'\text{R}$. This is the efficient direction of the wind, and its velocity may be represented by that diagonal, when that of the wind in its true direction is represented by $\text{W}'\text{M}$: consequently the impulse of the wind perpendicularly to the plane of the sail must be represented by $\text{P}.\text{A}.\,w'\text{M}^2.\,\sin.^2 w'\text{M}z$. By this impulse motion is produced in the ship in the direction of its keel, and the whole expression may be made equal to $\text{A}'.\text{P}'.\text{V}'^2$, the former expression for the resistance of the water. The values of $\text{W}'\text{M}$ and of M R, that is, V and V', the absolute velocities of the wind and ship, and also the angle $\text{L M W}'$ being known, the value of $w'\text{M}$ may be computed.



When the direction of the wind is not coincident with the line of the ship's keel, its power to impel the ship forward will be increased by placing the sail in some oblique position, as Y Z. In this case let M C, perpendicular to Y Z, represent the velocity with which, if not resisted by the water, the ship would move by the action of the wind. Then, by the resolution of motions, letting fall C D perpendicularly on K L, M D and D C will represent the velocities in those directions; and, in the case of equilibrium between the actions of the wind and water, the resistance of the latter against the side of the ship perpendicularly to the keel will be to that against the bow, parallel to the keel, as C D to D M, or as tang. ∠ C M D to radius. Let A'' be the area of a vertical section through the immersed part of the ship in the direction of the keel, and A', as before, the area of the vertical section perpendicularly to the keel; also suppose that, in consequence of the reaction of the water, the ship's motion, instead of being in the direction M C, should be in some other, as M E. Then, V' representing the velocity of the ship in this direction, and the resistance of the water being supposed to be proportional to the square of the velocity and square of the sine of the inclination, we have $\text{P}'.\text{A}''.\text{V}'^2 \sin.^2 \text{E M D}$ for the resistance of the water against the ship's side, and $\text{P}'.\text{A}'.\text{V}'^2 \cos.^2 \text{E M D}$ for the resistance against the bows. Therefore

$$\tan.\ \text{C M D} : \text{radius} :: \text{A}'' \sin.^2 \text{E M D} : \text{A}' \cos.^2 \text{E M D};$$

consequently, the ratio of A′ to A″ being supposed to be known, the value of Z M D, that is, the ship's lee-way, might be found. If Z M D = 45°, and the ratio of A″ to A′ be assumed to be as 12 to 1, the lee-way will be found to be 16° 6′; and if Z M D = 30°, the lee-way will be 20° 49′. But experiment alone can determine this element, for, with equal velocities and equal quantities of sail, it varies in different ships; and, in the same ship, with the velocity, and the disposition and quantity of the sail.

Let M N represent the velocity of the ship in the direction M E; then w M, the diagonal of the parallelogram W N, will represent the efficient velocity of the wind in that direction, W M being the true direction of the velocity, and letting fall on Y Z the perpendicular w Z, this last line will represent the velocity perpendicularly to the sail. Therefore the force of the wind in this direction will be proportional to $w Z^2$; then drawing w Q parallel to M E, to meet Z Q drawn through Z perpendicularly to M E and w Q, we have Z w Q equal to the complement of Z M E, and consequently $w Z^2$ being resolved in the direction M E or w Q, becomes $w Z^2$ cos. Z w Q, or $w Z^2$ sin. Z M E. But w Z varies as sin. ∠ w M Z; therefore the force of the wind to impel the ship in the direction M E is proportional to $\sin^2$. w M Z sin. Z M E; and the force of impulse being proportional to the square of the velocity produced by it, it follows that the velocity of the ship will vary with sin. w M Z $\sqrt{}$ sin. Z M E. Now making the differential of this expression equal to zero, considering w M E as constant and Z M E as variable, it will be found that this product is a maximum when ∠ w M E is so divided that tan. w M Z : tan. Z M E : : 2 : 1, or that sin. (w M Z − Z M E) = $\frac{1}{3}$ sin. w M E.

In Maclaurin's 'Fluxions' (art. 912) there is given an investigation of the angle W M Z, between the true direction of the wind and the plane of the sail, when the velocity of the ship's motion in M E is a maximum. The general expression is complex, but when the direction of the wind is perpendicular to the ship's course we have tan. W M Z =

$$\sqrt{\left\{2+\frac{9}{4}\frac{v'^2}{v^2}\right\}}+\frac{3}{2}\frac{v'}{v};$$

v′ being the velocity of the ship and v that of the wind.

Therefore, if the velocity of the ship were very small, we should have tan. W M Z = $\sqrt{2}$ nearly, or W M Z = 54° 44′ nearly. But, on making v′ equal to $\frac{1}{4}$, $\frac{1}{3}$, and $\frac{1}{2}$ of v, we obtain for ∠ W M Z the several corresponding values 61° 27′, 63° 26′, and 66° 58′. It may be observed also that, if both ∠ Z M E and v are given, the velocity of the ship will be a maximum when the angle W M Z is a right angle, or when the sails are perpendicular to the true direction of the wind.

In the same work (art. 917) there is given the investigation of an equation from which may be determined the angle Z M E, between the plane of the sail and the line of the ship's motion when the velocity is a maximum; and from that equation it is inferred (art. 919) that, if the wind is perpendicular to the sail, the velocity is the greatest (provided the velocity of the ship before the wind be not less than one-third of the velocity of the wind) when sin. Z M E : radius : : $(v-1)^{\frac{2}{3}}$: 1·5874; the velocity of the ship being expressed by unity, and v, the true velocity of the wind, by a multiple of that velocity. It may also be inferred from the same equation, that if the velocity of the wind be such as to cause the velocity of the ship to be greater than one-third of itself, the ship will sail faster when the course is oblique to the wind than when coincident with its direction.

The force of the wind, which is denoted by P. A. $w M^2 \sin.^2$ w M Z sin. Z M E, being made equal to P′. A′. V'^2 (which will express the resistance of the water, if A′ represent the area of the immersed section of the ship perpendicularly to M E), the value of V′, the velocity of the ship, might from thence be obtained; and from the expression of that value it may be seen that, while the other terms remain the same, the velocity of the ship varies with the relative velocity of the wind and ship, with the sine of its inclination to the plane of the sail, and with the square root of the area of the sail. Hence also, when the velocity of the wind and both the area and position of the sail are constant, the velocity of the ship varies with sin. w M Z; that is, with the sine of the angle made by the apparent direction of the wind with the plane of the sail. It may be inferred from the general equation, that, by sufficiently increasing A and the angle w M Z, the velocity (V′) of the ship may be made to exceed w M, which is that of the wind.

If it were required to find the course of the ship and the position of the sails, so that the ship might recede most rapidly from any point of danger, as from a lee-coast situated, for example, in the position indicated by M′ P′, at right angles to w M, the direction of the wind; we must imagine M P to be drawn parallel to M′ P′, that is, perpendicular to w M. Then, the velocity of the ship in the direction M E being represented by sin. w M Z $\sqrt{}$ sin. Z M E, let this velocity be resolved into the direction perpendicular to M P; that is, let it be multiplied by sin. E M P: the ship will recede most rapidly from M′ P′ when the expression sin. w M Z. sin. E M P $\sqrt{}$ sin Z M E is a maximum. On making the differential of this expression equal to zero, we shall find that the velocity perpendicularly to M P is the greatest when ∠ w M P is divided so that the tangents of the angles w M Z, Z M E, and E M P are to one another as the numbers 2, 1, and 2. If the velocity of the ship be very small, we shall have ∠ w M E, or its equal Z M P, = 54° 44′ nearly; and ∠ w M Z = 35° 16′ nearly. And since receding at right angles from a line M′ P′, when that line is perpendicular to the direction of the wind, is an advance towards the wind; it follows that the above value of w M Z will indicate the position which the sail should have with respect to the wind, in order that the ship may get to windward with the greatest possible velocity. If the velocity of the ship be taken into consideration, the angles w M E and w M Z will, as before, be modified by the relation between the velocities of the ship and wind.

Since the lee-way, which a ship always makes when her sails are oblique to the direction of the wind, destroys the equality of the reaction of the water which would take place on the two bows if her movement were in the direction of her keel, and gives rise to an excess of pressure against the lee-bow; it follows that in these circumstances the ship's head is constantly forced to windward, and that the tendency of the ship to turn on the axis of the rotation is so much greater as the bows are more acute. To oppose, in some measure, this tendency, the quantity of sail in front of the centre of rotation, is greater than that which is behind it; but, notwithstanding such disposition, it always requires some movement of the rudder to complete the counter-action.

SAIL-MAKING. The canvas used for sails is a very stout material, woven in England or Scotland from Russian hemp, and purchased in the form of rolls called *bolts*, each bolt containing about 40 yards of canvas 24 inches wide. There are six or seven different qualities of this canvas, according to the size and position of the sail to be made; and each quality has a particular number attached to it, and must have a certain weight per square foot. Thus, in the Royal Navy, a bolt of No. 1 canvas, containing 38 yards, must weigh 44 lbs.; whereas No. 7 weighs only about half as much: the intermediate numbers having intermediate weights.

As the canvas is only two feet wide, many breadths are required to form a large sail. The mainsail of an East Indiaman contains nearly 700 yards of canvas; while the whole suit of sails for such a ship requires as much as 9000 yards. As the sails vary much in shape, considerable tact is required in cutting up the canvas so as to avoid waste. The art of the sail maker consists not only in seaming up the numerous breadths, so as to give the requisite dimensions to the sail, but also in strengthening the sail by sewing rope to its edges. The seaming and sewing are effected with large three-sided needles, of seven or eight different kinds, which are threaded with sewing twine having from 200 to 400 fathoms to the lb. The skeins of twine previous to being used are dipped into a trough, containing melted tar, grease, and oil, which is afterwards dried. The sail-maker has a thumb-stall and a palm-thimble, for protecting his right hand. His stitches have a regulated degree of closeness, on which his rate of payment in part depends; there are usually about 100 stitches in a yard. The overlapping of the breadths is an inch or an inch and a half. Besides the seaming, sundry small pieces of canvas are stitched to the sail to strengthen it in various directions; and the edge-rope or bolt-rope is sewn on with great firmness. So skilfully is the canvas marked out and cut up by a master sail-maker, that in the 9000 yards for the forty sails of a large ship, there will not be more than three or four yards actually wasted.

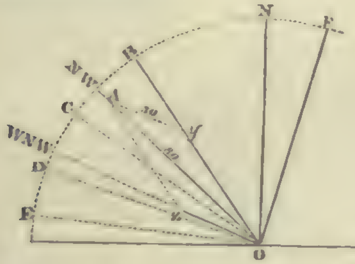
The *storm sails* patented in 1844 by Mr. Archibald Trail are made in the usual manner, but are subsequently strengthened by sewing to their surface a number of canvas bands about an inch broad, with cords woven in them, such bands being secured at their ends into the bolt-ropes, or cords forming the boundaries of the sail, and carried diagonally across the surface of the sail at an angle of 45° with the seams, and at a distance of about three feet from each other. Two sets of bands are used, crossing the sail in opposite directions, one set being attached on each side of the canvas. By this simple contrivance the strain is so equalised as to render tearing less probable than with an ordinary sail; while, if any injury be inflicted, the rent is confined within the narrow limits of one of the diamond-shaped compartments into which the sail is divided by the protecting bands.

SAILINGS; or THE SAILINGS. The various modes in which the calculations of a ship's true course are conducted, have already, under the head RECKONINGS AT SEA, been referred to individually, as forming part of a seaman's "day's work," or *dead reckoning* as it is called; distinctive of such portions of his work as depend on observation of the heavenly bodies. In this article it is proposed to review the peculiarities of the sailings with reference to the great problem of the accurate navigation of the surface of a sphere.

Under the word NAVIGATION the subject has been treated rather as the practice of a general system; and its details have been partly referred to under the terms COMPASS, GREAT-CIRCLE OR TANGENT SAILING, LONGITUDE AND LATITUDE, &c. It remains then to treat of the relative values of the various means of estimating a ship's true position by means of certain operations called "sailings."

In considering first the nature of the most simple form of navigation, namely, plane sailing, but which is only available for small spaces on the earth's surface and in low latitudes, the following diagram will assist.

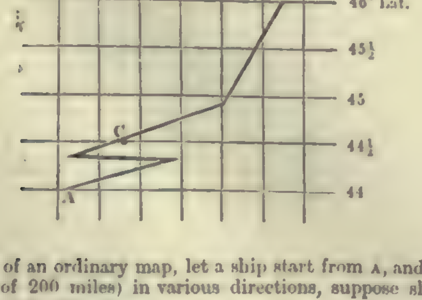
Suppose for example, a ship bound to a port bearing true N.W., distance 80 miles or knots. Her average general velocity to be 8 knots per hour. A W.N.W current to be setting at the rate of 3 miles per hour. The terrestrial deviation on the compass to be 2 points westerly. The ship's local attraction upon the average course to be 16° westerly: while, moreover, the wind being north-easterly (true), and the ship being nearly close-hauled, we should allow about 1 point leeway. It is obvious that with so many elements of disturbance an approximate course must be selected before starting. Now, the unscientific ship-master would guess at his course, and if he found himself by subsequent observation or otherwise, setting either to leeward or the reverse, would so vary his course as to attempt by time-losing experiments to finally reach his destination; while the complete navigator would probably proceed thus:—He would either roughly calculate his true course, having in his mind's eye the following figure, or would construct the figure itself, as under:—



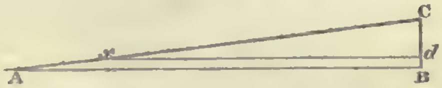
Let O represent the ship's position at starting, and A the intended port. It is usual to take the current as a course and distance. We get the approximate distance by saying in this case 8 : 80 : : 3 : 30. O z will, therefore, represent in position and magnitude the current course and distance; compounding the ship's bearing and distance from her intended port, and the set of current, as *forces* [COMPOSITION], we get the parallelogram O z A y, and the ∠ A O y (composed with the N.W. line O A) will be the course, which measured from north would be about N. 32½° W., or by calculation, thus: O A being given as 80, and bearing N.W., and O z being given 30, bearing W.N.W., the ∠ z O A would = 2 points: hence in the triangle A O y we have given the two sides and included angle O A y (= z O A) to find the rest by trigonometry. From this it would be seen that starting from O, in the direction O y, would, as influenced by the current, carry the ship along the resultant O A to its intended port at A, were no other influence at work. But perhaps the most difficult portion of a mariner's duty is to clear his course from compass errors. To continue the example:—after projecting the 2 points variation westerly from B to C, and the 16° W. by local attraction [LOCAL ATTRACTION] from C to D, and the 1 point leeway (westerly) from D to E, we find that the correction for leeway and compass error amounts in this case to the correction B E, which, measured to the eastward of O B, gives the true course which must be steered by compass to be O F, or instead of about N. 32½° W., it should be about N. 18° E.

Whatever method of sailing we adopt, the above mode of correction is indispensable; but with the exception of terrestrial deviation, the amount of correction to be applied depends chiefly on the judgment, and perception, and vigilance of the navigator.

Middle latitude sailing has already under the article RECKONINGS AT SEA been partially explained as regards its application to practice; its *principles* will now be briefly considered. The meridians of the globe meeting at the poles, the parallels of latitude diminish in magnitude as they recede from the equator; but as each parallel circle must contain 360° of longitude, it evidently follows that the term degree of longitude is one of only relative value, depending on the latitude at which it is situated: and when we estimate longitude by turning (as the phrase is) departure into longitude, the assumption of its latitude is either obtained by using middle latitude sailing, which adopts a mean between the latitude left and that arrived at, or by Mercator's sailing, which in most cases is more accurate. The questions will be better understood from the following figure:



On a portion of an ordinary map, let a ship start from A, and after a day's run (say of 200 miles) in various directions, suppose she finds herself at B. By middle latitude sailing the mean between the paralle left and that reached would be $\frac{44° + 46°}{2} = 45°$, but if we measure along the track sailed, it will be found that one-half the distance sailed would actually fall to the southward of 45°, or at C; hence the inaccuracy of middle latitude sailing in finding the longitude. Of course the remedy for this would be to divide the track into portions, and find the difference of longitude for each. When near the equator where the meridians are not so convergent, middle latitude sailing may be used with very trifling error; but Mercator's sailing is at such places less accurate, because, as the following figure will show, a small error in the course would make a large error in longitude.



In this, C x would be the distance run, and the angle A C B the course, d x the departure, and A B the difference of longitude.

Parallel sailing is used when the ship makes no difference of latitude, but sails upon a parallel of latitude. It is only preferred for its simplicity, because in "running along a parallel" the distance is the departure, and the true course is east and west: but it is at the expense of accuracy, for a ship thus sails along an arc of a circle instead of its chord, although at first sight the reverse appears to be the case. It is however certain, that the shortest distance between two points on the surface of a sphere is the arc of a great circle, the plane of which passes through the earth's centre. Now, if in the following *fig.* 1, we draw on a right sphere, *ab*, equal to the parallel of 40°, and assume the points thereon at *c* and *d*, the nearest distance between them will appear to be *c d*. This may be shown to be incorrect if the parallel of 40° be drawn in *fig.* 2 on gnomonic projection, where the chord *c e d* connects the two points and is their nearest distance; hence the curve *c e d*, in *fig.* 1, is the nearest distance between the points *c* and *d*, because its plane would pass through the centre, while the plane of *c d* would be parallel to it. But these errors might be avoided altogether by the use of great circle sailing, and especially as Mr. Saxby has rendered the finding of a great circle course more easy than even the Mercator's; as already fully explained under GREAT CIRCLE, OR TANGENT SAILING.

Fig. 1.

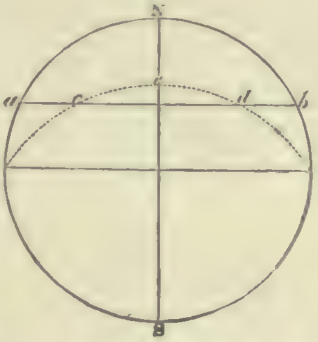
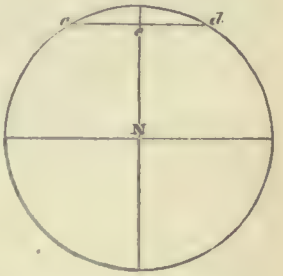
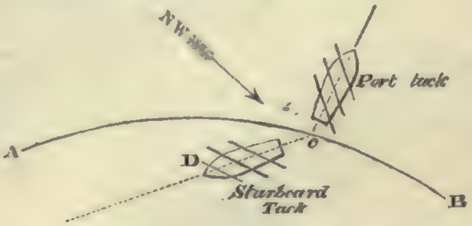


Fig. 2.



Windward sailing is a term used in connection with great circle sailing, by which is implied the advantage taken of the changes in the course of a ship when sailing upon the tangents of a great circle, and is such that a considerable saving of distance in a voyage may be effected when a ship is opposed by contrary winds, in determining on which "tack" to sail with reference to the great circle track itself. For example, suppose that a ship starting from B towards A on a great circle track, as drawn upon a Mercator's chart, meets at C with the wind N.W.; if her captain puts her upon the port tack, he absolutely sails away from his proper course, while by keeping her on the starboard tack, as at D, he sails in a direction nearly parallel to it.



Oblique sailing is merely a term applicable to those problems in which no right angle appears in the projected triangle. It is a mere term of oblique trigonometry, such as occurs in setting off one's position by cross bearings of objects whose relative bearing and distance from each other are well known.

Composite sailing was so called, and ably illustrated by Mr. Towson, but the subsequent invention of the Spherograph has rendered it as a sailing quite unimportant.

Having thus explained the usual resources of the navigator in his work of calculation under *systems* of progression, the subject may be viewed from another point. The comparative steadiness of large steamers on the ocean, and the greater advantages they possess in their partial independence as to the direction of the wind, might seem to be a relief to the ship-master; such is, however, counterpoised by the extreme difficulties inherent in steam navigation, and especially in iron ships. It is true the courses of steamers are more direct and free from "traverses," but it is the question of local attraction, ever liable to vary, which needs all the vigilance of the commander. This important subject has been treated of under Local Attraction, but we may add that Professor Airy has further illustrated his previous investigation by a very valuable communication read before the Institution of Naval Architects on March 1st, 1860.

SAILORS. [Ships; Seamen.]

SAINFOIN, *Onobrychis sativa,* is a plant of the family of the *Leguminosæ,* which grows luxuriantly and spontaneously on the calcareous soils of the middle and south of Europe. It has been in regular cultivation for upwards of two centuries for the purpose of supplying fodder for cattle, either in the green state or when converted into hay. There are few plants which have more rapidly improved the value of poor, thin, calcareous soils than sainfoin; and in the richer kinds of loam, which contain a considerable proportion of calcareous matter, its value surpasses even that of broad clover, giving fully as great a return, with a much smaller expenditure of manure. The plant has a strong woody and fibrous root, which insinuates itself into the fissures of calcareous rocks, and finds moisture in the driest seasons, while its spreading fibres keep the earth from being washed down the steep slopes of the hills. Being nearly perennial, or at least of many years' duration, it binds the soil together. In favourable situations it may be made into hay twice in the year, or cut oftener as green fodder. In the most arid and exposed situations it gives at least one good crop of hay. The plant grows about two feet high, and the stem, which branches out into many compound leaves, is crowned with a beautiful spike of papilionaceous flowers. After it has been mown it shoots out rapidly again, and may be advantageously depastured by every kind of cattle or sheep. There are varieties of the plant which differ in the rapidity of their growth: the best is called in France *esparcette,* or *sainfoin à deux coupes.* From France it has been introduced into England. The duration of sainfoin depends on the nature of the soil, and the state it was in with respect to weeds when it was sown. A cold wet subsoil soon destroys the roots, whereas a free and dry one, whether rocky or gravelly, gives them vigour. Grass and weeds, which choke the crown of the plant, soon cause it to decay, as is the case with lucern. With every advantage, it may last in vigour ten years, especially if it be occasionally invigorated with a top-dressing of manure. During that time it may be cut for hay every year, taking care to cut it before the flower is faded or the seed formed; and if sheep are folded on the aftermath, the next crop will well repay the trouble. It is usually sown in spring in a crop of barley or oats, which should be sown thin in order that the sainfoin may not be smothered. The land should have been prepared by a cleansing crop, such as turnips fed off by sheep folded on them. From three to four bushels of rough seed may be sown, harrowed in, and rolled. It is not often drilled, although this method, by allowing the use of the hoe between the rows, would much strengthen the young plants, and protect them against coarse grasses, which are their greatest enemies. In the first year the sainfoin should not be fed off by sheep; and if it is mown, it should not be mown too close to the ground. The crown of the root in the young plant rises a little above the ground, and if this be bit off or cut with the scythe the plant dies. It is useful to harrow the ground lightly, to draw the earth round the roots, and to destroy the seed-weeds soon after the barley or oats are reaped. The sainfoin does not produce a large crop the first year, for some of the seeds will lie a twelvemonth in the ground before they spring up. It is in perfection after the second year, when a portion may be reserved for seed. Sainfoin hay is extremely nourishing for every kind of cattle, especially if it has been made without rain. Although it is not apt to heat in the stack, it must be put up in a very dry state; and if it has suffered from rain too much care cannot be taken thoroughly to dry it, for the water insinuates itself into the hollow stems, and is long in evaporating, so that when it feels quite dry it may yet contain much water. The mode of discovering this is to twist it strongly in the hands into a rope, when the moisture, if there is any, will ooze out. It is better to let it dry thoroughly, than, by carrying it in a hurry, to run the risk of its becoming mouldy within. In very precarious seasons it may be carried in a half-dried state, provided there be no moisture in it from dews or showers, and stacked in alternate layers with good straw. It will impart some of its fragrance to the straw, and lose none of its nutritive qualities. The same may be done with lucern or clover. The most advantageous use of sainfoin, however, is to cut it green and give it immediately to the cattle. There is little danger of their being hoven by it, for it ferments very slowly, owing to the fibrous nature of the stem. If the situation of the field admits of occasional irrigation, without danger of the water stagnating, the produce of the sainfoin will be greatly increased; and it has been known to be cut four or even five times in a season without exhausting its strength. When it begins to appear thin on the ground, and other plants seem to get the better of the sainfoin, it is time to break it up. The land will be found much improved in fertility by the sainfoin. A poor chalk or gravel, which before would scarcely repay the seed sown in it, will now, by the gradual decay of the roots and fibres of the sainfoin, produce good crops without manure. If clean, it may be ploughed up for wheat; if foul, as it is most likely to be, it may be pared and burned, and yield a crop of turnips, to be partly fed off and followed by barley. Many a poor barren tract of calcareous rock and gravel has been fertilised and raised in value by the sole effect of the sainfoin, without which it must have remained in its unproductive state.

Although a chalky soil is best adapted to the growth of sainfoin, it may be sown with advantage in all light calcareous loams, provided the substratum be sound and dry. On very rich deep moulds lucern is a more profitable crop; but sainfoin will thrive where lucern will fail, and it is particularly adapted for poor dry soils.

There is nothing peculiar in the manner in which sainfoin is made into hay. It should not be shaken about too much, but treated as clover is, for fear of injuring the flower and breaking off the leaves. The swathe should be merely turned over when dry on one side, and then, as soon as it is dry through, it should be put into small cocks, turned once or twice when the dew is off the ground, and carried to the stack as soon as it is sufficiently made. It should take a good heat in order to make it compact, but without acquiring too dark a colour. Experience alone can teach the exact time when it should be stacked. When it is left for seed, it should be examined carefully after the blossom fades. The lower pods will be filled with ripe seed before the blossoms at the top of the spike of flowers are withered or the seed formed in them. If the sainfoin were left standing till these seeds were ripe, the lowest would be shed; but by cutting it at a proper time these may be preserved, while most of the latter will ripen in the straw sufficiently to vegetate when sown. Rainy weather is very injurious to the seed crop; a fine time should therefore be selected, if possible, even at the risk of a smaller crop. The produce varies from three to five, or even six, sacks per acre. It is easily threshed out, and this operation is often done on a cloth in the field, when the weather permits. It is readily done by a threshing-machine, and winnowed like corn. On the whole, there are few plants the cultivation of which is so advantageous as that of sainfoin on the limestone soils on which it thrives best.

SAINT, derived from the Latin "sanctus," through the French "sainct," properly signifies a holy or pious person, and is so used in the Christian church. From the commencement of the Christian religion, great veneration was always shown to persons remarkable for their holiness or piety, and their memory was cherished after their death. In course of time it became the custom to implore departed saints to assist the living by their prayers and intercessions with the Deity; and as man has in all ages felt the want of a mediator between himself and the Deity, the practice of praying to saints increased rapidly, and superstition multiplied the number of such mediators to so great an extent, that it was at length found necessary to put some restraint upon the practice. It was accordingly decreed by the ecclesiastical councils in the 9th century, that no departed Christian should be considered as a saint to whom prayers might be addressed, until the bishop in a provincial council, and in the presence of the people, had pronounced him worthy of that honour. Even in that century many divines thought that it was proper that the decisions of bishops and councils should be confirmed by the consent and authority of the pope, who was regarded as the supreme and universal bishop. It was not, however, till the following century that any person was sainted by the bishop of Rome alone; and this honour was first conferred on Udalric, bishop of Augsburg, by John XV. Shortly afterwards the privilege of declaring departed Christians to be saints was confined to the pope; and the creation of saints was distinguished by the name of "canonisation."

The invocation of saints in the Roman Catholic church is frequently stigmatised as idolatry; and the Church of England condemns the Romish doctrine on the subject as "a fond thing vainly invented, and grounded upon no warranty of Scripture, but rather repugnant to the word of God." (Article xxii.) In this, as in any other case of religious controversy, it is right to take the account of the doctrine from the persons who believe in it, and not from a statement of their opponents. Thus Bellarmine says, "It is not lawful to ask of the saints to grant to us, as if they were the *authors* of divine benefits, glory, or grace, or the other means of blessedness. This is proved, first, from Scripture: 'The Lord will give grace and glory.' (Psalm lxxxiv.) Secondly, from the usage of the church; for in the mass prayers and the saints' offices we never ask anything else but that at their prayers benefits may be granted to us by God. Thirdly, from reason; for what we need surpasses the power of the creature, and therefore even of saints; therefore we ought to ask nothing from saints beyond their impetrating from God what is profitable to us. Fourthly, from Augustine and Theodoret, who expressly teach that saints are not to be invoked as gods, but as able to gain from God what they wish. However, it must be observed, when we say that nothing should be asked of saints but their prayers for us, the question is not about the words, but the sense of the words. For, as far as words go, it is lawful to say, 'St. Peter, pity me, save me, open for me the gate of heaven;' also, 'give me health of body, patience, fortitude, &c.,' provided that we mean 'save and pity me by praying for me;' 'grant me this or that by thy prayers and merits.' For so speaks Gregory Nazianzen, and many others of the ancients." ('De Sanct. Beat.,' i. 17.) The doctrine of the Roman Catholic church is explicitly stated in the council of Trent: "Though the church has been accustomed sometimes to celebrate a few masses to the honour and remembrance of saints, yet she doth not teach that sacrifice is offered to them, but to God alone, who crowned them; wherefore neither is the priest wont to say, I offer sacrifice to thee, O Peter, or O Paul, but to God." (Sess., 22.)

The Lives of the Saints have been written in the 'Acta Sanctorum,' 51 vols. fol. [BOLLANDUS, JOHN, in BIOG. DIV.]; and in Alban Butler's 'Lives of the Saints,' 12 vols. 8vo.

SAINT ANTHONY'S FIRE. [ERYSIPELAS.]

SAINT ELMO'S FIRE. [LIGHTNING.]

SAINT MARTHA WOOD. [BRAZIL WOOD.]

SAINT VITUS'S DANCE. [CHOREA.]

SAL ALEMBROTH. [MERCURY. *Bichloride of Mercury.*]

SAL AMMONIAC. [AMMONIUM, *Chloride of.*]

SAL ENIXUM. [POTASSIUM: *Bisulphate of Potash.*]

SAL MIRABILE, a name formerly applied to sulphate of soda.

SAL PRUNELLA. [POTASSIUM. *Nitrate of Potash.*]

SALE is that transaction by which the ownership of property is transferred to the buyer, in consideration of a money payment by him, or on his behalf, to the seller. Such transfer of ownership may sometimes be made, although the property does not belong to the seller; as in the case of sales in open market, which are valid, though made by parties wholly without title to the property, or authority to sell it; and sales by factors and agents duly authorised. Under the present head it is proposed to treat only of the law relating to the simple act of sale, it being assumed that the parties to the sale are legally qualified to effect it. Persons in certain conditions are by law in some cases restrained and in others disabled from buying and selling, but these restrictions and disabilities form no part of the law of sale; they belong rather to those branches of the law, such as infancy, bankruptcy, insolvency, coverture, lunacy, alienage, &c., which create and define them.

Generally, all things may be the subject of sale; but there are some exceptions,—such are a mere title to lands of which a party is not in possession, a presentation to a living actually vacant, the pay of a naval or military officer, and some other things.

Property is distributed under the two heads of real and personal property, which differ materially in many respects; and the modes of effecting the sale of each of these kinds of property likewise materially differ. Some incidents, however, are common to a sale both of real and personal property.

No sale is valid so as to be capable of being enforced unless—

1st. The parties to it act with good faith;

2nd. Unless there is consent in each of them; and,

3rd. No sale is valid the subject of which is illegal, or which involves an illegal transaction, or has for its object an illegal act.

With respect to the first principle, it is a maxim of the common law that fraud vitiates all contracts. The fraud may be, with respect to the property, the subject of sale, either of a positive character, such as wilful misdescription of it in some material particular by the seller, or negative, such as a designed concealment of defects and incumbrances. In these cases the contract of sale cannot be enforced, notwithstanding express stipulations that the property shall be taken with all its faults, or that misstatements shall not invalidate the sale, but shall be provided for by compensation.

What is a material particular, will of course depend upon the subject-matter of the sale and the circumstances of the case. A misdescription of the situation of an estate, a statement that a public-house which was bound by covenant to purchase beer of a particular brewer was a free public-house, that a long leasehold estate was freehold, have been held to be material. Under this head may be adduced as an instance the employment of more persons than one to make false biddings at an auction on behalf of the seller. Such persons are commonly called puffers. One such person may lawfully be employed to protect the interests of the seller by merely buying in the property at a predetermined sum. But the bidding of more than one has the effect of inducing an incorrect opinion as to the value of the estate, and such bidding, being fraudulent, invalidates the sale. In like manner fraud on the part of the buyer will have the same effect; as where he prevents other persons from purchasing by fraudulently misrepresenting the nature of the property, or attempts to obtain possession of it with a design not to pay for it; or where, when negociating the sale, he knows himself to be insolvent, or makes payment by cheques or bills which he knows will not be honoured, &c. These are instances of fraud which is intended to operate only on one of the parties to the sale. But the same effect may be produced where the fraud is intended to operate on other persons not parties to the sale; as where a sale is attempted to be made by a seller for the purpose of defrauding his creditors. If in such case the buyer participate in the fraudulent intention, the sale will be invalid. In an action at law, the question whether fraud has existed is to be determined by the jury.

2. There must be consent in each of the parties to the sale. This rule involves the proposition that each must be a free and intelligent agent: no sale therefore can be valid where either of the parties was under coercion by violence or imprisonment, or bodily fear, or was lunatic, or idiot, or utterly intoxicated. Again, in order that a buyer may be a legally consenting party to a sale, he must be truly informed in all material particulars as to the property which is the subject of sale. This must be understood of such particulars as he cannot by reasonable care and observation inform himself upon, for a man has no legal protection against the consequences of his own carelessness and negligence. If, however, he has been deceived in any other particulars, even unintentionally, by the buyer, he cannot be said to consent to the bargain. The consent which he gives is to the purchase of such property as has been described to him, and the consent therefore cannot relate to the property which is the subject of the sale, if it differs in material points from what has been described. Thus in the common case of a horse warranted sound, the consent is to buy a sound horse, and the buyer cannot be considered to have consented to buy an unsound horse. If therefore the horse is manifestly unsound, a party cannot be compelled to carry into effect his contract to purchase it. The case is the same with an estate said to be tithe free, which in reality is not so, or with any other property the description of which, as stated, varies materially from the truth. Where indeed the variance from the description is obvious, and the buyer has had an opportunity of inspecting the property and afterwards chooses to complete the purchase, the contract will not be invalid. The reason of this rule is manifest, for the legal presumption is that ordinary diligence has been used, where it might and ought to have been used, and there is therefore no ground for supposing an absence of the buyer's consent.

In cases where there is no fraud, and a possibility of variance from the description is contemplated in the conditions of sale, the sale may still be valid notwithstanding the existence of such variance, for in this case both parties knowingly take the chance of the variance being either favourable or adverse to them. As when for instance it is stated that an estate consists of so many acres, &c., be the same more or less, &c. If the conditions of sale contain a provision that compensation shall be made for such variances when they are ascertained, then the party in whose favour they turn out to be, will be bound to make such compensation. If, however, from the circumstances of the case it should appear that such compensation cannot be made, the sale cannot be enforced against the purchaser, forasmuch as the terms to which the parties consented are impossible, and there is therefore nothing to which the consent is applicable.

A court of equity will in some cases compel a buyer to complete his bargain, on the condition of the seller making him compensation in respect of those matters in which there is a variance, even although there is no provision to that effect in the conditions of sale. The principle on which this is done is, that parties ought to carry into effect what was substantially their intention. This power of the court therefore is not exercised where the variance is material, or where the attainment of the particular matter in which a variance exists really was the main object of the purchase. The common terms of exaggerated praise in which persons speak of the property that they have to sell, is not such misdescription as will make a sale void. In cases where property is agreed to be sold by one contract, in one lot, a buyer cannot be compelled to take some part of it without the rest.

3. No sale is valid if the subject matter of it is illegal or prohibited, or if an essential part of it is an illegal transaction or involves an illegal act. A sale of treasonable, blasphemous, or obscene publications is void, for the acts of treason, blasphemy, and obscenity are legally punishable. A sale of property known by the seller to be intended to be used for illegal purposes is void, such as drugs to be used for the adulteration of provisions, or a house to be occupied for the purposes of prostitution. Sales for the purpose of avoiding the forfeiture to the crown incident upon judgment after a conviction for felony, are void. Sales to an alien enemy are unlawful, although a power exists in the crown to grant licences legalising such sales. Offices of public trust, such as those which are connected with the administration of justice or government, either in the United Kingdom or in the dependencies upon it, cannot lawfully be made the subject of sale. The enactments affecting the sale of various articles are too numerous to be referred to here. It may, however, be laid down generally that where a thing is prohibited and made unlawful by statute, a contract for the sale of such thing is void, even although the statute does not enact that it shall be so, but only attaches a penalty to an infringement of its provisions. Sales of contraband articles are also void; and even in the case of a foreigner selling goods abroad, to be delivered in this country, the sale will be invalid, if he be cognisant of and aiding in an attempt to introduce them into this country in contravention of the revenue laws. A sale of property in the ordinary course of a party's trade is void if made on a Sunday, although the sale of the same article by another person whose ordinary dealings are not in such matters would be valid.

In case of a sale of lands, it is assumed that the seller has a good title to them, and that he will deliver over the title-deeds to the buyer. In failure of either of these particulars the sale cannot be enforced. The right to receive a good title is one which is conferred upon the buyer by the law, independently of any agreement between the parties.

By the statute 29 Charles II., c. 3, s. 4, certain forms were required in order to give effect to a sale of "lands, tenements, or hereditaments, or any interest in or concerning them." Such forms are no part of the sale, which consists in the consent of parties who are competent to consent, but the statute merely declares that such consent shall, in certain cases, have no legal effect, unless the prescribed forms are observed. If an agreement for sale has been made without the requisite formalities, and has been carried into effect in some material part, a court of equity will enforce the performance of the whole contract, on the ground that the informal contract, having been partly completed, is not a case within the statute. In all other cases of contracts as to interests in land, "the agreement, or some memorandum or note thereof, shall be in writing, and signed by the party to be charged therewith, or by some other person thereunto by him lawfully authorised." The agreement binds the party who signs it, although it is not signed by the other party. No established form is requisite, and it is not necessary that the agreement should be contained in one instrument: it may be collected from a series of letters, or a written offer followed by a written acceptance, or from documents referred to by a letter. The signature may be attached to any part of it. An agent may be appointed verbally, and the same person may act as agent for both parties to the sale. An auctioneer is such agent, and his writing down the name of the highest bidder in his book is a sufficient signature.

The law which relates to the construction of agreements for sale falls under the ordinary rules as to the construction of agreements generally. The same observation applies as to the remedies which parties possess for the enforcement of them. When the contract for the sale of an estate is completed, the estate is, in equity, considered to be sold, and the buyer is viewed as the owner of the estate, and the seller as only a trustee for the buyer, while the buyer is considered as a trustee of the purchase-money for the seller. If, therefore, a party has contracted for the sale of an estate of inheritance, and die before payment of the purchase-money, the money will be considered as part of his personal estate, and his executors will be entitled to it. On the other hand, if the party who has contracted to buy the estate die before it is conveyed to him, his heir or devisee will be entitled to the estate, and the executors must pay the purchase-money out of the personal estate of the buyer, if they have sufficient assets. It is a consequence of this equitable doctrine, that the buyer must, as a general rule, bear any loss which happens to the estate after the completion of the contract of sale. A person who has obtained such an equitable ownership may deal with the property in all respects as if it were his own; and such dealings, though not valid at law, are viewed as valid transactions in a court of equity.

With respect to sales of personal property, the common law required no formalities. The terms of sale might be agreed on either verbally or in writing; and they might be proved by any evidence legally applicable to the proof of other matters. Sales of goods made at one time, and not together exceeding in price 10*l.*, still remain on this footing. By the same statute (29 Chas. II., c. 3) which prescribed certain formalities in sales of land, it was enacted (s. 17) that "no contract for the sale of any goods, wares, and merchandise for the price of 10*l.* sterling and upwards shall be allowed to be good except the buyer shall accept part of the goods so sold and actually receive the same or give something in earnest to bind the bargain, or in part payment, or that some note or memorandum in writing of the said bargain be made and signed by the parties to be charged by such contract or their agents thereunto lawfully authorised." By the 9 Geo. IV., c. 14, s. 7, the enactments of this act are extended to all contracts for the sale of goods of the value of 10*l.* sterling and upwards, notwithstanding the goods may be intended to be delivered at some future time, or may not at the time of the contract be actually made or fit for delivery. The statutory requisites are thus four in number:—

1. Delivery and receipt of part of the goods.
2. Payment of earnest.
3. Payment of part of the price.
4. A signature of a memorandum of the bargain by the party or his agent. By the performance of any one of these requisites the parties to the sale are bound.

If the goods themselves are delivered to the buyer himself and accepted by him, of course no question can arise as to the completion of the bargain. Where, however, the delivery is not to him personally, many cases of nicety occur as to whether or not a delivery has taken place, so as absolutely to vest the property of the goods in the buyer. A delivery which would be sufficient, if not afterwards interfered with by the seller, to accomplish the requisite of the statute, is complete as soon as the goods have been delivered to a carrier for the purpose of being conveyed to the buyer, even although the carrier has not been selected by the buyer. But during the course of actual transit to the place indicated by the buyer to the seller as the place of destination, the goods are subject under certain circumstances to a right of the seller to detain them. This is called the right of stoppage in transitu, and the time and place when it ceases are often a question of great nicety. [STOPPAGE IN TRANSITU.] Where no delivery of part of the goods themselves has been made by actual removal, a constructive delivery may effect the same purpose: a delivery of the key of the warehouse where the goods lie; the receipt of rent for their warehouse-room by the seller; the endorsement and delivery of a bill of lading or a dock warrant; an order to a wharfinger to deliver, &c., amount to a delivery. In all such cases, however, it must be understood that the delivery is not complete if anything yet remains to be done to the goods on the part of the seller, such as their separation by weighing or measurement from a larger bulk. Again, the exercise of ownership over the goods by the buyer, with permission of the seller, is an act legally equivalent to delivery: such as marking the goods, tasting wine, and cutting off the pegs from the cask, &c. But in these cases it must distinctly appear that the act which is done is an act of ownership; if done with any other view, as for the purpose merely of identifying the property, it will of course afford no ground from which a delivery may be inferred. Where a sample is taken out of the whole bulk sold, a delivery of the sample operates as a part delivery.

2. The earnest-money paid must be retained. In a case where a shilling had been paid to bind a bargain, and was returned, it was held that this was not a compliance with the requisite of the statute.

3. The part payment need not necessarily be made in cash; a payment by acceptance of a bill, or by a promissory note, will, while the instruments remain undishonoured, have the same effect as by actual money.

4. The general observations which have been made as to a note or memorandum in writing relative to sales of land, will apply equally to one relative to sales of goods.

(Sugden, '*On the Law of Vendors and Purchasers*;' Ross's '*Treatise on the Law of Vendors and Purchasers of Personal Property.*')

SALEP, *Salap*, or *Saloop*, a nutritious article of diet, much valued in the East for its supposed general stimulant properties, but which is justly esteemed as bland and nutritious, and well suited to children and convalescents. Salep consists of the tubers of different species of *Orchideæ*, which have been known in medicine from very early times by the name *Orchis*. All the European saleps are far inferior to and considered only as indifferent substitutes for that brought by commerce from Africa. Salep is highly valued in India, and forms an article of commerce from Cabul and Cashmere to the north-western provinces of India, where it is sold, at the Hurdwar fair held in April, at a high price. This is very similar in form and appearance to Turkey salep, though the tubers are twice as large as the best procurable in London.

All the plants that yield salep have two tubers, charged with nutritious matter; while one is nourishing the flower-stem and seeds of the current year, by which it is robbed of its store, the other serves as a reservoir for the flower-stem of the succeeding year. This last alone is fit for use. Both are dug up together, but the solid one only is retained. It is dipped in warm water, after which the fine brown skin is easily removed by means of a coarse cloth or brush. The tubers, being thus peeled, are arranged on a tin plate, and placed within an oven heated as for baking bread; here they remain for seven or ten minutes, in which time they exchange their opaque and milky whiteness for a semi-transparent horn-like appearance and a yellowish colour, retaining their original bulk. Being then withdrawn from the oven, they are exposed during some days to dry and harden in the air; or, by the employment of a very gentle heat, they may be brought to the same state in the course of a few hours. All that is then required to adapt the salep for food is to boil it in water (or milk) to the required consistency. In Armenia, the tubers, while yet soft, are strung together on threads, and suspended in the sun to dry without artificial heat. The chemical composition of salep varies according to the period of growth when the tubers are taken up. Though salep is regarded as a variety of starch, there is very little pure starch present, the chief constituent being that form of gum termed *bassorine*. With cold water salep very slowly swells and forms a mucilage; but one part of salep-powder with forty-eight parts of water boiled or heated forms a thick mucilage, which has very peculiar qualities, inasmuch as with either calcined magnesia, bisulphate of quinnia, or biborate of soda, it thickens into a solid glue-like substance. The chief use of salep is as a mild and digestible article of food; and as the orchis abounds in our meadows, a large supply of nourishment might be obtained by digging up the tubers and drying them, as above stated, and as was recommended in the last century by Dr. Percival ('On the Preparation, Culture, and Use of the Orchis-root,' 1773).

Salep is composed chiefly of bassorine, some soluble gum, and a little starch; by some it is considered as containing the largest portion of nutritious matter in the smallest space. Its presence in small quantity in milk retards the tendency of that fluid to become sour. It is a harmless and useful ingredient in the preparation of bread, and is free from the objections to potato-starch, which is too often used by bakers in the place of wheaten flour.

SALERNITANA SCHOLA, will be found under this head in the BIOG. DIV.

SALHYDRAMIDE. [SALICYLIC GROUP.]

SALICIN. [SALICYLIC GROUP.]

SALICOR, the ash of the plant *Salicornia annua*. It is produced on the French coast of the Mediterranean, and is used in the manufacture of carbonate of soda, of which it contains about 15 per cent.

SALICYL. [SALICYLIC GROUP.]

SALICYLAMIDE. [SALICYLIC GROUP.]

SALICYLIC ACID. [SALICYLIC GROUP.]

SALICYLIC GROUP. A cluster of chemical substances, compounds or derivatives of the electro-negative radical *salicyl* ($C_{14}H_5O_4$). The members of this group—itself a subdivision of the benzoic series in Gerhardt's arrangement—are numerous; including the odoriferous oil of meadow-sweet and of winter-green, and the bitter principle of willow-bark.

Salicyl ($C_{14}H_5O_4$) itself has not yet been isolated. As it contains the elements of *phenyl* ($C_{12}H_5$) and *carbonic acid* (C_2O_4), and as, moreover, its compounds are not unfrequently converted into bodies identical with derivatives of phenyl, the salicylic group has sometimes been termed the *phenyl-carbonic group.*

Salicylide of benzoyl ($C_{14}H_5O_4, C_{14}H_5O_2$), *parasalicyl*, or *spirine*, is obtained by acting upon chloride of benzoyl with hydride of salicyl, or from the destructive distillation of salicylide of copper. It is insoluble in water, soluble in alcohol or ether, crystallises in prisms, melts at 260°, and sublimes at 356° Fahr., and is converted into picric acid on being boiled with nitric acid.

Hydride of salicyl ($C_{14}H_5O_4, H$); *salicylous acid*; *spirous acid*, or *essential oil of spiræa ulmaria.* Besides the method of obtaining this body from the flowers of meadow-sweet, as described under ESSENTIAL OILS, it may be produced by decomposing salicin under the influence of oxidising agents. According to Buchner, such an operation is simply an imitation of what occurs naturally in the *spiræa* flowers; the buds of this plant contain salicin, and have scarcely any smell; but, on expanding, freely expose their parts to the air, when oxidation of the salicin goes on, and hydride of salicyl results, giving odour to the flowers. The artificial oxidation of salicin is conveniently effected by bichromate of potash. To two parts of salicin, two of bichromate of potash, and sixteen of water, in a retort, are added three of oil of vitriol, previously diluted with eight parts of water. After a short time a gentle heat may be applied, when the oil passes over; twenty-five parts of salicin yielding six of the essence. The salicin for this process need not be pure; indeed, aqueous extract of willow-bark serves very well.

When quite pure, hydride of salicyl is a colourless oil, but from contact of air soon acquires a red hue. It has an agreeable aromatic odour, acrid taste, boiling point 360° Fahr., specific gravity 1·173, vapour density 4·276, and burns with a bright smoky flame. It is somewhat soluble in water, the solution giving a deep violet colour with persalts of iron. Hydride of salicyl is an acid body: it decomposes the alkaline carbonates with effervescence, and combines with bases generally to form neutral and acid *salicylides.* The potassium salts contain respectively $K, C_{14}H_5O_4 + 2$ Aq. and $K, C_{14}H_5O_4 + H, C_{14}H_5O_4$.

Chlorosalicylous acid ($C_{14}(H_4Cl)O_4, H$), *bromosalicylous acid* ($C_{14}(H_4Br)O_4, H$), *iodosalicylous acid*, and *hydride of nitrosalicyl* ($C_{14}(H_4NO_4)O_4, H$), are respectively produced by the action of chlorine, bromine, iodine, and nitric acid upon hydride of salicyl. They are crystalline compounds, and form crystalline salts with bases.

Salhydramide, *salicylimide*, or *hydride of azosalicyl* ($C_{42}H_{18}N_2O_6$) is the product of the action of ammonia upon hydride of salicyl:—

$$\underbrace{3C_{14}H_6O_4}_{\text{Hydride of salicyl.}} + \underbrace{2NH_3}_{\text{Ammonia.}} = \underbrace{C_{42}H_{18}N_2O_6}_{\text{Salhydramide.}} + \underbrace{6HO}_{\text{Water.}}$$

It crystallises in prisms, is insoluble in water, slightly soluble in cold alcohol, and more so in hot alcohol.

Chlorosamide ($C_{42}H_{15}Cl_3N_2O_6$), or the hydride of chlorazosalicyl, and *bromosamide* ($C_{42}H_{15}Br_3N_2O_6$) or the hydride of bromazosalicyl, are formed on acting with ammonia upon the chlorine and bromine derivatives of hydride of salicyl.

Thiosalicol ($C_{14}H_6O_2S_2$), or hydride of sulphosalicyl, is a pulverulent substance, formed on treating salhydramide with sulphuretted hydrogen.

Sulphurous derivatives of hydride of salicyl, and of the preceding compounds of salicyl, result from the action of sulphurous acid upon their alkaline salts, or of the alkaline bisulphites upon the compounds themselves.

Salicin ($C_{26}H_{18}O_{14}$) is a neutral bitter principle contained in the bark of the various species of willow and poplar (sallow, osier, aspen, &c.). It readily crystallises out from a concentrated decoction of the bark, after tannic acid and colouring matter have been removed by hydrated oxide of lead.

When pure, salicin occurs in white silky crystals, soluble in water or in alcohol, but insoluble in ether or oil of turpentine. It melts at 248° Fahr., loses water at 392° Fahr., and at a higher temperature decomposes. Concentrated sulphuric acid communicates a blood red colour to it; the liquid, neutralised with chalk, yields a deliquescent chestnut-brown powder, containing, according to Mulder, *sulphorufic acid.* Water decomposes the red body formed by sulphuric acid; heat, also, gives rise to the formation of a resinoid body, that has been called by one chemist *olivin*, by onother *rutilin*, while a third thinks it to be *saliretin.* Several chlorine derivatives of salicin exist.

Saligenin ($C_{14}H_8O_4$) and grape sugar result from the action of boiling dilute acids upon salicin:—

$$\underbrace{C_{26}H_{18}O_{14}}_{\text{Salicin.}} + 4HO = \underbrace{C_{14}H_8O_4}_{\text{Saligenin.}} + \underbrace{C_{12}H_{14}O_{14}}_{\text{Glucose.}}$$

Hence salicin is one of the glucosides. Saligenin crystallises in colourless crystals, very soluble in boiling water, alcohol, or ether. It is partially volatile; most oxidising agents convert it into hydride of salicyl, while chlorine gives rise to trichlorophenic acid.

Saliretin ($C_{14}H_6O_2$) is a product of the action of heat upon saligenin in closed vessels; it is also produced by prolonged ebullition of saligenin with dilute acids. It is a white or yellow-coloured resinoid body, insoluble in water or in ammonia, but soluble in alcohol, ether, or concentrated acetic acid.

Helicin (2 ($C_{26}H_{16}O_{14}$) + 3aq.) is obtained on digesting salicin in ten times its weight of nitric acid of specific gravity 1·160 for about a day: hydrogen is thus removed from the salicin, water being formed, and helicin deposited in acicular crystals. It is inodorous, of slightly bitter taste, very soluble in boiling water or alcohol, but almost insoluble in ether. Chlorine and bromine act upon, and give rise to derivatives of, helicin.

Helicoidin ($C_{52}H_{34}O_{28}$ + 3aq.) seems to be a combination of helicin and salicin ($C_{52}H_{34}O_{28} = C_{26}H_{16}O_{14} + C_{26}H_{18}O_{14}$). It is produced when the oxidation of salicin by nitric acid is incomplete, or when the specific gravity of the acid is less than that above indicated.

Populin ($C_{26}H_{17}(C_{14}H_5O_2)O_{14}$ + 4aq.), or salicin in which an equivalent of hydrogen is replaced by benzoyl, has already been described. [POPULIN.]

Coumarin, a fragrant principle of several plants, seems to be allied to the members of the salicylic group, inasmuch as it yields salicylate of potash when fused with the hydrate of that base. It is further described in a separate article. [COUMARIN.]

Salicylic acid (HO, $C_{14}H_5O_5$). In combination with methyl this acid exists naturally in oil of wintergreen. [ESSENTIAL OILS.] On boiling the oil for a few minutes with solution of potash, neutralising by hydrochloric acid, and allowing the mixture to cool gradually, salicylic acid crystallises out in acicular tufts. Salicylic acid may also be formed by projecting salicin, in small portions at a time, into hydrate of potash fused in a silver basin, the temperature not being allowed to rise higher than 750° Fahr. On dissolving the mass in water and adding hydrochloric acid, the salicylic acid is precipitated, and may be purified by recrystallisation from boiling water.

Salicylic acid fuses at 316° Fahr., and at a higher temperature sublimes unchanged. It is soluble in alcohol, ether, or oil of turpentine. A mixture of peroxide of manganese and sulphuric acid oxidises it to formic acid. By ebullition with nitric acid it is converted first into nitrosalicylic acid and, finally, into picric acid. Distilled with excess of lime it is split up into carbonic and phenic acids. Its solutions give an inky-blue precipitate with persalts of iron, the colour disappearing on the addition of hydrochloric acid.

Salicylic acid decomposes carbonates with effervescence, and forms *salicylates* that are, for the most part, monobasic and crystalline. The potash salt contains (KO, $C_{14}H_5O_5$, aq.); the *double salicylate of copper and potash* has the formula $KO, C_{14}\left\{\begin{matrix}H_4\\Cu\end{matrix}\right\}O_6 + 4aq.$: it crystallises in beautiful emerald green plates.

Salicylic ethers.—Although the oil of wintergreen appears to be a definite salicylate of methyl ($C_2H_3O, C_{14}H_5O_5$), it nevertheless plays the part of an acid, and from its source has been termed *Gaultheric acid*: it still admits of the replacement of an equivalent of hydrogen by a metal or a radical, *gaultherates* being formed; thus:—

Gaultherate of potash . . .	$KO, C_{14}H_4(C_2H_3)O_5$
Gaultherate of methyl . . .	$C_2H_3O, C_{14}H_4(C_2H_3)O_6$

But this gaultheric acid or hydrate of methyl-salicyl admits of the substitution of an acid radical for hydrogen, and thus are formed:—

Benzoate of methyl-salicyl . . .	$\left.\begin{matrix}C_{14}H_4(C_2H_3)O_6\\C_{14}H_5O_3\end{matrix}\right\}$
Cuminate of methyl-salicyl . . .	$\left.\begin{matrix}C_{14}H_4(C_2H_3)O_5\\C_{20}H_{11}O_3\end{matrix}\right\}$

Similarly the ethyl-gaultheric acid, or rather hydrate of ethyl-salicyl, and the amyl-gaultheric acid, or hydrate of amyl-salicyl, on being acted upon by the chloride of benzoyl yields:—

Benzoate of ethyl-salicyl . . .	$\left.\begin{matrix}C_{14}H_4(C_4H_5)O_6\\C_{14}H_5O_3\end{matrix}\right\}$
Benzoate of amyl-salicyl	$\left.\begin{matrix}C_{14}H_4(C_{10}H_{11})O_5\\C_{14}H_5O_3\end{matrix}\right\}$

Chlorine and bromine derivatives of salicylic acid result from the action of chlorine and bromine on salicylic acid. Their formulæ are:—

Chlorosalicylic acid	$C_{14}H_5ClO_6$
Bichlorosalicylic acid	$C_{14}H_4Cl_2O_6$
Bromosalicylic acid	$C_{14}H_5BrO_6$
Bibromosalicylic acid	$C_{14}H_4Br_2O_6$
Tribromosalicylic acid	$C_{14}H_3Br_3O_6$

Nitrosalicylic acid ($C_{14}H_4(NO_4)O_6$ + 2aq.), called also *indigotic acid* and *anilic acid*, has already been described [Anilic Acid]. *Binitrosalicylic acid*, or *nitropopulic acid*, contains $C_{14}H_4(NO_4)_2O_6$.

Anhydrous salicylic acid, or *salicylic anhydride* ($C_{14}H_5O_5$, $C_{14}H_5O_5$), is formed by the action of oxychloride of phosphorus on dry salicylate of soda. It is a gummy or oleaginous-looking body, soluble in alcohol. It is converted into ordinary salicylic acid by boiling with solution of potash.

Salicylide ($C_{28}H_8O_8$) is a white, amorphous, pulverulent substance, formed in the preparation of salicylic anhydride. It is insoluble in ether, and almost insoluble in alcohol.

Salicyluric acid ($HO,C_{18}H_8NO_7$) is found in the urine, after salicylic acid has been taken into the stomach. Boiled with hydrochloric acid it splits up into salicylic acid and Glycocoll.

Chloride of salicyl ($C_{14}H_5O_4$,Cl) is a fuming liquid, obtained on acting upon oil of meadowsweet by perchloride of phosphorus.

Salicylamide ($C_{14}H_7NO_4$) results from the action of a strong solution of ammonia on the oil of wintergreen. It is a volatile solid, of yellow colour, soluble in boiling water, alcohol, or ether. By the action of the chlorides of benzoyl or cumyl upon salicylamide the following compounds are generated:—

$$\text{Benzoyl-salicylamide} \;\ldots\ldots\; N\left\{\begin{matrix} C_{14}H_5O_4 \\ C_{14}H_5O_2 \\ H \end{matrix}\right.$$

$$\text{Cumyl-salicylamide} \;\ldots\ldots\; N\left\{\begin{matrix} C_{14}H_5O_4 \\ C_{20}H_{11}O_2 \\ H \end{matrix}\right.$$

Nitrosalicylamide $N\left\{\begin{matrix} C_{14}(H_4NO_4)O_4 \\ H \\ H \end{matrix}\right.$ is the product of the action of ammonia on nitrosalicylate of methyl.

SALICYLIMIDE. [Salicylic Group.]

SALICYLOUS ACID. [Salicylic Group.]

SALICYLURIC ACID. [Salicylic Group.]

SALIENT, a term applied to an angle which presents its point to the outside of the figure, as opposed to the re-entering or re-entrant, which is applied to an angle presenting its point to the inside of the figure. These terms are frequently used in fortification, and seldom in geometry.

SALIFIABLE BASE, a term applied to any substance capable of uniting with an acid to form a salt. [Salts.]

SALIGENIN. [Salicylic Group.]

SALII were twelve priests of Mars Gradivus, who formed an ecclesiastical collegium or corporation at Rome. They were chosen from the patricians, and established by Numa to take care of the twelve ancilia, or sacred shields of Mars. The original ancile was said to have been found in the palace of Numa, and was supposed to have fallen from heaven. To secure its preservation, Numa commanded the armourer Mamurius Veturius to make eleven other shields exactly like it; and the twelve were deposited in the temple of Mars on the Palatine hill, and committed to the care of the Salii. (Liv., i. 20; Dionys., ii. 70, 71; Cic., 'Rep.,' ii. 14; Ovid. 'Fast.,' iii. 387; Festus, s. v. 'Mam. Vet.')

On the calends of March, and on several successive days, the feast of Mars was celebrated by the Salii, on which occasion they carried the shields through the city dressed in their official garments, which consisted of an embroidered tunic with a brazen belt, the trabea, and the apex, or conical cap, with a sword by their side, and a spear or staff in their right hand. They at the same time performed a dance, and sung hymns or songs called Axamenta in honour of Mamurius Veturius, and all the celestial deities, with the exception of Venus, (Macrob., 'Sat.,' i. 12; Virg., 'Æn.,' viii. 286; Varro, 'De Ling. Lat.,' vii. 26, ed. Müller.) These songs were in later times scarcely understood even by the priests themselves. (Quint., i. 6. p. 54, Bipont.; Hor., 'Ep.,' ii. 1, 86.) At this festival the Salii were accustomed to partake of an entertainment in the temple of Mars, which was proverbial for its magnificence and excellence. (Suet., 'Claud.,' 33; Cic. 'ad Att.,' v. 9; Hor., 'Carm.,' i. 37.)

Another corporation of Salii, also consisting of twelve members chosen from the patricians, was established by Tullus Hostilius in fulfilment of a vow which he made in a war with the Sabines. These Salii were also called Collini or Agonenses, to distinguish them from the Salii established by Numa, who were surnamed Palatini. (Dionys. ii. 70, iii. 32; Varro, 'De Ling. Lat.,' vi. 14.)

SALIRETIN. [Salicylic Group.]

SALITHOL. [Phenylic Group.]

SALIVATION, or PTYALISM, is a superabundant secretion of saliva. This sometimes occurs as an idiopathic disease, originating without any evident cause. Dr. Christison ('Treatise on Poisons') has collected several such cases, in some of which the quantity of saliva discharged amounted to three or more pints daily. Irritation of the salivary glands, or accompanied with profuse secretion, is also an occasional attendant on common inflammations of the throat and mouth, and on those that accompany eruptive diseases, especially small-pox. But far more frequently salivation is the effect of medicines or poisons. Some preparations of gold, copper, antimony, and iodine, croton oil, digitalis, and even opium, are apt to produce it; and it is almost a constant effect of the long-continued or copious administration of mercury.

The quantity of mercury required to produce salivation varies greatly in different persons. In some, two or three grains of calomel are sufficient; but by other persons such large quantities may be taken with impunity, that they appear insusceptible of its action. No general rule, therefore, respecting the quantity of mercury that may be safely given to any one can be made; but in no case can there be safety without caution and careful watching of the effects produced by it.

Salivation from the use of mercury is distinguished from that which arises from other causes by its being preceded by a peculiar brassy taste in the mouth, fœtor of the breath, and tenderness, redness, and sponginess of the gums. These are soon followed by the increased flow of saliva, and if mercury be still taken, or if the quantity already taken was very large, they increase; the whole mouth, tongue, face, and throat become swollen and tender, and ulcers and sloughs quickly form on the mucous membrane. In extreme cases, the mouth and cheeks and throat become extensively gangrenous, the teeth fall out, the gums swell up as they do in scurvy, the jaws are affected with necrosis, and by the spreading of the disease to important parts it may prove fatal; or the patient may die exhausted by the profuse discharge of saliva, or by the peculiar nervous and other constitutional disturbances that often accompany the poisonous influence of mercury. [Mercury.]

The best treatment of mercurial salivation is exposure to cool pure air, a nutritious diet, and mild purgatives. Gargles of chlorinated soda or lime are useful in correcting the fœtor of the breath; and honey, or the *Mel Boracis*, may be applied to the smaller ulcers in the mouth. The permanganates of soda and potash may also be employed with advantage as gargles and lotions. The more extensive ulcerations and the gangrene can be treated only by maintaining the patient's strength by tonics and stimulants, and by the usual local applications to such diseases. The idiopathic kinds of salivation usually require only cool air and gently reducing measures.

SALIX, *Medical Properties of.* The barks of several species of willow have been long celebrated for their astringent and antifebrile qualities; but from the great difficulty of determining the species, it is not ascertained which kind is entitled to the preference. The *Salix Russelliana* (Bedford willow) appears to possess the greatest quantity of *tannin*; but the peculiar principle termed *salicin* seems to exist in the largest proportion in the *S. Helix*, or rose willow; while the *S. pentandra L.* (the bay-leaved willow), possesses, both in its bark and leaves, the largest amount of bitterness and resin, and a most balsamic odour. The barks of *S. alba*, *S. fragilis*, and *S. caprea* (or great round-leaved willow, which yields the broad-leaved willow bark), are also gathered, often indiscriminately. Whichever species is selected, the bark should be stripped in spring from branches not less than three years or more than six years old, and from trees growing in moist rather than swampy places. It should be carefully dried in the shade. The fresh bark has a faint odour somewhat resembling bitter almonds; the dried bark is devoid of odour. The taste is at first mucilaginous, afterwards bitter and astringent. The degree of astringency may be easily tested by adding to a decoction of the bark a solution of gelatine. Tincture of nut-galls does not affect it. According to the analysis of Pelletier and Caventou, the bark of *S. alba* contains a green fatty matter similar to that of cinchona, a yellow slightly bitter colouring matter, tannin, resinous extract, gum, wax, woody fibre, and an organic acid, which with magnesia forms a salt easily soluble in water and alcohol. Since these analyses, salicin has been found. [Salicylic Group; Salicin.]

Willow bark possesses astringent, tonic, and febrifuge qualities, which render it a valuable substitute for cinchona, and as it often suits the stomach better, it is well calculated for the treatment of agues among the poor. In debility of the stomach and relaxation of the mucous membranes, it is often very serviceable. In the latter cases, an infusion, made with cold water, of the powdered bark of *Salix pentandra*, is preferable; but any of the others may be made equal to it by the addition of bruised cinnamon bark. Like all astringent tonics, it is often useful as an anthelmintic.

Salicin has febrifuge properties, but they are much weaker than those of quinia; it must therefore be given in considerably larger doses. It may be given in substance or solution, and also in conjunction with many other salts, without undergoing decomposition or entering into combination. "In its passage through the system it undergoes oxidation, and is converted into hydruret of salicyle, which is found in the urine. Its presence is detected by a persalt of iron, which strikes an intense violet colour with urine containing it." (Pereira.) Of this property advantage might be taken in the treatment of some renal complains.

The barks of many species of willow contain a valuable dyeing principle. It is capable of dyeing drab with the help of a mordant only. For this purpose bitartrate of potass (cream of tartar) is best. If the bark be macerated in one vat, and the water then containing the colouring principle be drawn off into another vat, the mordant can then be added, and the stuff immersed in it. For the production of drab colour four materials are generally used, the shade resulting being often uncertain and varying in the same piece of cloth, in many spots being *foxy*, as it is technically termed.

SALSEPARIN. [SMILACIN.]

SALT. [SODA; SODIUM: MANURE.]

SALT CAKE. [SODIUM; *Sulphate of.*]

SALT OF SATURN, an old name for acetate of lead.

SALT OF SORREL. [OXALIC ACID. *Binoxalate of Potash.*]

SALT OF TARTAR. [POTASSIUM: *Carbonate of Potash.*]

SALT OF TIN. [TIN. *Protochloride of Tin.*]

SALT AND SALT TRADE. The chemical nature of common salt, as a chloride of sodium, is treated under SODIUM. The vast stores of rock-salt and salt-brine in Cheshire and Worcestershire, whence England obtains her supply, are described in the GEOG. DIV., under such headings as CHESHIRE, DROITWICH, NANTWICH, NORTHWICH, &c. A few additional details in this place are all that will be needed.

A rocky bed is the source of nearly all our inland salt; but as subterranean streams flow over this bed and become saturated with salt, the original form is changed. It is simply a question of manufacturing convenience, whether to raise the solid salt and purify it by dissolving, boiling, evaporating, &c.; or to raise the liquid brine and operate upon that. The salt-works adopt the latter course in most parts of England; but at Northwich they also operate upon a rocky kind of salt, which is transparent and colourless, and is loosened by blasting. There are other kinds of rock salt, much rougher and darker. On many parts of the coast salt is obtained from sea-water, at places called *salterns;* but as the salt would be too costly if evaporated by heat, the makers mostly rely on the slow process of evaporation by exposure to the open air. At Lymington both methods are combined.

In Cheshire the brine springs have been known and worked from very early times, but the bed of salt whence the brine is obtained was not known until about two hundred years ago. In the pits, the rock salt is loosened much in the same way as coal, by blasting and by the pick, and is brought to the surface to be dissolved in water. The brine springs in the valley of the Weaver mostly spring from a depth varying from 10 to 60 yards. The brine is pumped by steam power into large cisterns, where it is more completely saturated by an addition of rock salt. The brine then passes through wooden troughs to the evaporating pans, large flat open vessels with flues underneath. The evaporation, and the conversion into grains or crystals of salt vary according as *common* salt, *stoved* salt, *flakey* salt, *fishery* salt, &c., are to be produced; but in all, the crystals are allowed to form, and are then removed to the drying house. The blocks of common salt familiar in the shops are produced by transferring the crystals from the pan to wooden moulds, whence they are removed to be dried.

Nearly the whole of the salt exported is made in Cheshire, and is sent down the river Weaver, which communicates with the Mersey, to Liverpool. The sources of supply are said to be inexhaustible; and latterly the salt-manufacturers have so far extended their works, that the opening of new markets would be of the greatest advantage to them. The Staffordshire rock-salt is chiefly exported from Hull, and that of Worcestershire from the port of Gloucester.

A duty of 10*s.* per bushel was laid on salt in 1798, which in 1805 was increased to 15*s.* In 1823 this duty was reduced to 2*s.*; and on the 5th January, 1825, was wholly repealed. Salt used in the fisheries was always duty-free, and in 1821 the quantity so used was 2,406,602 bushels; and about 150,000 bushels, required by bleachers, was also exempt from the duty. A duty of only 5*s.*, which was afterwards reduced to 2*s.* 6*d.*, was charged on salt used for agricultural purposes. During the existence of the duty, the retail price was 4½*d.* per lb.; it is now about ¼*d.* Salt is now used more largely than hitherto by the poor, and is employed in manufactures and in agriculture to an extent which is only compatible with cheapness.

In 1852 an estimate was made that 300,000 tons of salt were used in the United Kingdom annually for domestic purposes, 200,000 tons for manure and manufactures, and 500,000 tons exported. In that year the prices varied from 2*s.* 6*d.* to 12*s.* per ton. The aggregate value of the whole was set down at 350,000*l.* In Cheshire only, in that year, there were 29 salt mines and 97 salt works belonging to 47 proprietors, employing 8000 persons, and an invested capital of 1,000,000*l.* In 1858 the total produce was believed to have risen from 1,000,000 tons to 1,400,000 tons annually, of which about one half is exported. If the above figures are correct, the domestic consumption must be far more than 16 lbs. per head, which was an estimate made several years ago. In 1858, the salt-manufacturers of Cheshire and Worcestershire memorialised the government, praying that means might be adopted for facilitating the consumption of British salt in India and China. A relaxation had been made in 1846, by which British salt was admitted under certain conditions into India; and the memorialists asked for still more favourable conditions. As for China, they suggested that, in any treaty between the two countries, a demand should be made for the admission of British salt, either free or under a small duty. The Cheshire manufacturers have, in fact, more salt than they know what to do with; and they are looking out for an extended market. At present, the two best customers are Calcutta and New Orleans, each of which takes about 80,000 tons a-year.

SALTPETRE. [POTASSIUM: *Nitrate of Potash.*]

SALTS. The term salt, originally restricted in its application to common salt, which it still means when used merely by itself, is now applied to a vast number of substances which have in many cases few properties in common.

Common salt is the principal of a class composed of a metal and such bodies as chlorine, iodine, bromine, and fluorine, and the radicals of the hydracids, and which are included by Berzelius in his class of *haloid-salts* (from ἅλς, sea-salt, and *εἶδος*, form), because in constitution they are analogous to sea-salt. The whole series of the metallic chlorides, iodides, bromides, and fluorides, such as chloride of sodium, iodide of potassium, and fluor-spar, are, as well as the cyanides, sulphocyanides, and ferrocyanides (though the three last are very differently constituted from the former), included by Berzelius in his list of haloid-salts.

It was for many years admitted as an unquestionable fact that common salt was a compound of muriatic acid and of soda; and hence it was very commonly called muriate of soda. But it has been shown by Davy, that the acid and alkali during their action on each other suffer mutual decomposition; and that while water is formed by the union of the hydrogen of the acid with the oxygen of the alkali, the chlorine of the former and the sodium of the latter unite to form chloride of sodium. It has since been proved that this occurs with all so-called *hydracids*, when they act upon metallic oxides: thus hydrochloric acid and soda give chloride of sodium and water, hydriodic acid and soda yield iodide of sodium and water, and hydrocyanic acid, cyanide of sodium and water, &c.

While then the hydracids, by the decomposition which they suffer, do not yield *hydro-salts* with the metallic oxides, yet hydro-salts may be formed by saturating these acids with the vegetable alkaloids; for example, hydrochloric and hydriodic acids yield respectively hydrochlorate and hydriodate of quinine, when made to act upon this base. With ammonia hydrochloric acid forms the salt called sal-ammoniac; but these salts are analogous to the chlorides, chloride of ammonium being formed by the conversion of the ammonia into ammonium, by the transference of the hydrogen of the hydrochloric acid to the ammonia, which is theoretically supposed to consist of one equivalent of nitrogen and four equivalents of hydrogen, instead of one equivalent of nitrogen and three equivalents of hydrogen, which exist in ammonia.

The *oxy-salts* form another numerous and important class of compounds: these are formed when an oxacid is made to combine with an oxidised base; as, for example, when sulphuric acid unites with soda, the result being sulphate of soda. The sulphates of potash, lime, magnesia, &c., are similarly constituted; but a question has arisen whether these salts are not also analogous to the chlorides, in containing a metal rather than an oxide; thus, instead of supposing that sulphuric acid, composed of one equivalent of sulphur and three equivalents of oxygen, is combined with soda, formed of one equivalent each of sodium and oxygen, it has been, and with much plausibility, supposed that the oxygen is transferred to the sulphuric acid, forming a compound which has never yet been isolated, consisting of one equivalent of sulphur and four equivalents of oxygen, and that this is combined with sodium. Professor Daniell proposed the name of *oxysulphion* of sodium for such compound, while Professor Graham denominates it a *sulphat-oxide* composed of *sulphat-oxygen* and sodium.

Another class of bodies has been described by Berzelius as coming within the description of salts; namely, the sulphur-salts. Electro-positive sulphides, termed *sulphur-bases*, are usually the protosulphides of electro-positive metals, and therefore correspond to the alkaline bases of those metals; and the electro-negative sulphides, *sulphur-acids*, are the sulphides of the electro-negative metals, and are proportional in composition to the acids which the same metals form with oxygen. Thus sulpharsenious acid (AsS_3) and sulpharsenic acid (AsS_5) combine respectively with sulphide of potassium (KS) to form the sulpharsenite and sulpharseniate of potassium. These salts obviously correspond with the arsenite and arseniate of potassium. Hence, if the sulphur of a sulphur-salt were replaced by an equivalent quantity of oxygen, an oxy-salt would result.

In general properties the various classes of salts, and indeed the individuals of the same class, differ as widely as possible; some are crystallisable, others uncrystallisable; they are colourless, and of various colours; sapid and insipid; soluble and insoluble in water, alcohol, and other menstrua; volatile and fixed in the fire; decomposable or undecomposable by the same reagent.

Salts have been conveniently, though not quite correctly, divided into alkaline, earthy, and metallic salts; for, strictly speaking, most of the two former belong to the latter, and to these classes must be added the ammoniacal salts and the salts of the vegetable alkaloids. Again, salts constituted of the same elements may contain one or other in excess; thus soda and various other bases combine with three different portions of carbonic acid. The first is the *neutral* carbonate, containing one equivalent each of acid and of base; the second contains one-half more carbonic acid, and is called the sesqui-carbonate; and the third contains twice as much carbonic acid as the first, and is the bi-carbonate.

Super-salts are such as contain an excess of chlorine or of acids, and sub-salts such as contain excess of base. Dr. Thomson has proposed—and it is very conveniently adopted in practice—to describe the degree of excess of acid in the super-salt by Latin terms, and that of the excess of base by Greek: thus while a compound of two equivalents of chlorine and one of a base, or of an acid and base, is called a bi-chloride or bi-sulphate, as the case may be, a compound containing one equivalent of chlorine or acid to two of base, is termed a *di-chloride*, &c. [CHEMICAL NOMENCLATURE: *Nomenclature of Salts.*]

SAMARITAN CHARACTERS, are the old Hebrew characters, which were disused by the Jews during the Babylonish captivity, but retained by the Samaritans, from which circumstance, and especially from their being used in the extant copies of the Samaritan Pentateuch, they have obtained their present name. They are nearly the same as the Phœnician characters. [ALPHABET; HEBREW.]

SAMENESS or IDENTITY. This term is generally applied to what is called personal identity, or the sameness of a living and intellectual being, as man. There are some remarks on this subject by Bishop Butler in his 'Dissertation of Personal Identity.'

The sameness of objects which are external to a man consists in the perception of a variety of circumstances as to these external objects and at different times, from which arises an opinion of sameness in a certain sense. A man sees a tree growing in a certain place, and he may have remembered it for many years. But in the mean time the tree may have increased a hundred-fold in bulk, and therefore its substance is not the same as that of the tree which he first saw there; and besides this, there may not be a single particle of matter the same in the tree at two remote times of his observation. The tree then is by the supposition not the same in a strict sense; but for all practical purpose it is called and is the same. A man can no more believe that all the change that the tree has undergone belongs to some other tree, than he can believe that the growth of his own body belongs to another being than himself.

When sameness is applied to a living and intellectual being, it includes both the matter of the body and something else. A man can have no doubt that his body is not entirely the same in youth, in middle age, and in old age. He can view his body as he does any thing external, and he has a belief that it undergoes changes, and is therefore not the same in the strict sense. But yet he considers himself the same person; person here including something besides the body, whether that something be a property of an organised body or something else. Locke, as quoted by Butler, says, "that the consciousness of our own existence, in youth and in old age, or in any two successive moments, is not the same individual action, that is, not the same consciousness, but different successive consciousnesses." Butler's answer to this vague talk is sufficient. But more may be said. How is consciousness of our personal identity, or if this form of words be objected to as a way of begging the question, how is the thing called "consciousness of our existence" at any two successive moments shown to be "not the same consciousness, but different successive consciousnesses?" What are successive moments in a man's consciousness of his own existence? It is more consistent with that consciousness which we have, to say that the consciousness of our personal identity is one and the same always; and if it is allowed that there is in man a belief that he is at different times the same being, in some sense which he cannot otherwise explain than that he feels that he is, it follows that this consciousness of personal identity is one indivisible thing, that it is as continuous as the personal identity itself which it presupposes. Nor is it any objection that a man's faculties may be temporarily impaired by illness, and he may lose the exercise of his reason and recover it; or an accident may befall him, which for a time renders his bodily and mental powers inactive, though he may finally recover both. On his recovery he does not doubt that he is the same person that he was before his illness or accident, and therefore his consciousness is one. The division of consciousness by successive times, corresponding to certain external signs, and the making that supposed succession a ground of objection to personal identity, is to confound things that are unlike, and to apply a measure to both that does not fit one of the things.

"Every person," says Butler, "is conscious that he is now the same person or self he was, as far back as his remembrance reaches." This cannot be disputed. It is a bare fact that this consciousness does exist in us. We have not this consciousness from the time of our birth up to manhood and old age: it does not go further back in its particular manifestations than our remembrance does; yet we doubt not that we, the man, were once that particular child of our parents rather than any other child of these parents or of any other parents. But this belief is derived from evidence: our consciousness in its particular manifestations does not extend farther back than our remembrance. Yet remembrance does not make personal identity, as Butler remarks: "Consciousness of personal identity presupposes, and therefore cannot constitute personal identity, any more than knowledge, in any other case, can constitute truth, which it presupposes."

The remembrance of particular things is a very different thing from the consciousness of personal identity. When this consciousness begins, when it ends, how its activity is suspended, we know not: but we know that it is a law of our nature that, in the ordinary state of a man's bodily and intellectual faculties, he has a perception, whatever it may be and however it may arise, whenever he reviews certain acts of his own or events in his life, that he the perceiver, and no other person, is the agent or is the person affected by these events. The remembrance then merely makes the consciousness of personal identity active; and this consciousness of personal identity is not constituted of the remembrance of different acts or events, but is as permanent and uninterrupted as the animal life itself, which nobody supposes to consist of successive lives, but to be one life. And it should be observed that the question of personal identity only arises upon the suggestion of the memory. Every man all through his life feels that he is in some sense or in some way, which he expresses by that term "is." And he is never without this present consciousness of existence. There is therefore an uninterrupted consciousness, which, as already observed, is one, and not divisible by a measure of time. The remembrance of any particular act of a man's own or of any event in his own life, is a present act, and the consciousness of such present act of memory accompanies the act of memory as it does any other present act; and as the act of memory is retrospective, so is the consciousness of that act of memory retrospective, but only incidentally, according to the nature of the act. The memory merely directs the conscious agent to an act of the kind called passed, and to a passed act of such a kind that the consciousness of sameness in the agent is inseparable from the notion of the act that is remembered.

SAMIELI is the Turkish name of a wind which the Arabs call *samoom*, or *simoom*, which in Egypt is called *khamsin*, and in Senegambia and Guinea *harmattan*. It occurs in most countries which are situated at no great distance from sandy deserts, and it blows always from that quarter in which the desert is situated. Thus, in Senegambia and Guinea it blows from the north-east; in the Delta of the Nile from the south-south-west and south-west; on the eastern shores of the Gulf of Suez from the north-east; in Syria from the south-east; at Mecca from the east; at Bagdad from the west; at Basra from the north-west; and at Surat from the north. These winds are extremely hot, and a considerable quantity of fine sand is generally suspended in the air, which has been collected by the winds in rushing over the desert. They affect the human body very powerfully, producing great feebleness, and sometimes even death. They usually consist of a quick succession of hot and cold puffs of wind; and the difference of the temperature between these puffs, which is stated to amount to more than twenty degrees of Fahrenheit's thermometer, is probably one of the reasons of their effect on animal bodies being so great. It is also thought that the hot puffs bring a pestilential air, as a putrid and sulphureous smell is perceived when they blow. Formerly it was asserted that the hurtful effects of the wind could be avoided by a person throwing himself on the ground with the mouth downward; but modern writers say that the Arabs disapprove of such a proceeding, and perhaps justly, if it is true that the hot air is heavier than the atmosphere. To diminish the effects of the wind, the Arabs cover their faces with the *kefieh*, a handkerchief which they wear on their heads.

SAMPHIRE, a herb used in some parts of the country as a salad and pickle. The true samphire is the *Crithmum maritimum*, a plant belonging to the natural order *Umbelliferæ*. It is a very succulent plant, with pale green leaves, and flowers arranged in umbels. It grows on rocks by the sea-side. The species of *Salicornia* [SALICORNIA, in NAT. HIST. DIV.] are often called samphire, and are used in the same manner; but they are inferior to the *Crithmum* as an article of diet.

SANCTIFICATION, a term in theology, denoting the highest Christian attainment; the state of those who are perfectly pure and holy, having lost the inclination to vice, and are wholly devoted to virtue and godliness. It is understood to be produced by the special operation of the Holy Ghost, and to ensue upon justification.

SANCTUARY, a consecrated place which gave protection to a criminal taking refuge there. The word also signifies the privilege of sanctuary, which was granted by the king for the protection of the life of an offender. Under the dominion of the Normans there appear early to have existed two kinds of sanctuary, one general, which belonged to every church, and another peculiar, which commenced and had its force in a grant by charter from the king. This peculiar sanctuary could not be claimed by prescription only; and it was also necessary that it should be supported by usage within legal memory, and allowance before the justices in eyre. These two kinds differed from each other with respect to some of their privileges. The general sanctuary afforded a refuge to those only who had been guilty of capital felonies. On reaching it, the felon was bound to declare that he had committed felony, and came to save his life. [ABJURATION OF THE REALM.] A peculiar sanctuary might, if such privilege was granted by the charter, afford a place of refuge even for those who had committed high or petty treason; and a party escaping thither might, if he chose, remain undisturbed for life. He still, however, had the option to take the oath of abjuration and quit the realm. Sanctuary seems in neither case to have been allowed as a protection to those who escaped from the sheriff after being delivered to him for the purpose of execution. During the latter part of the reign of Henry VIII., at the time when the religious houses were dissolved, several statutes were passed (26 Henry VIII. c. 13; 27 Henry VIII. c. 19; 32 Henry VIII. c. 12), which regulated, limited, and partially abolished the privilege of sanctuary, both as regarded the number and classes of criminals entitled to it, and also the places possessing the privilege. Finally, by 21 James I. c. 28, s. 7, it was enacted that no sanctuary or privilege of sanctuary should thereafter be admitted or allowed in any case [ABJURATION OF THE REALM; ASYLUM.]

(Reeves's *History of the English Law;* Comyn's *Dijest*, tit. 'Abjuration;' 4 Bl., *Com.*)

SAND. The fine angular materials derived from the disintegration of rocks, and deposited according to the gravity of the various particles under the action of running water, are technically known by the generic term "*sands.*" They are, for the purposes of classification, subdivided into river sand, sea sand, and pit sand; volcanic, calcareous, argillaceous, or silicious sand; red, yellow, or white sand; according to their manner of occurrence, their qualities, or their colour. In the arts they are used for many purposes, but as their applications in the manufacture of mortar, of plastic building materials, and of glass, are, perhaps, of the greatest practical importance, attention will be principally called to these applications; but before doing so it may be of interest to observe that the sea-sands on some parts of the shores of the Atlantic are largely used in agriculture, on account of the large quantity of calcareous and nitrogenous matters they contain. This application of sand, of the description known locally by the name of "tangue," prevails in the departments of the Calvados, Manche, Côtes du Nord, &c., in France, to a very great extent, and it is found to be very beneficial.

For mortar making, sands may be selected according to the properties of the lime in connection with which they are employed, as under some circumstances they play a very important part in the chemistry of the hardening of the mortars. As was said under MORTAR, the value of that class of materials depends upon the rapidity and the energy with which the double silicate of lime and alumina is formed; and it therefore follows that the sands which contain the various ingredients in a state susceptible of entering into combination with the lime, are those which are of the greatest value. The sands derived from the destruction of the purely silicious rocks are for the most part totally inert for the purposes under consideration, because the silica they contain is in a permanent crystalline form; but the sands derived from the destruction of gneiss, grauwacké, felspathic granites, and other rocks, in which the silicious acid does not exist in a stable compound, are easily acted upon by pure caustic lime. Thus it is found that in the north of Spain, and in the granitic district of the north of France, the decomposition of the felspathic granites of those districts has produced a sand in which the silicate of lime of the felspar exists in a state able to combine with the pure hydrate of lime, there obtained by slaking the caustic lime derived from the more pure crystalline limestones. The volcanic sands, known technically by the names of *pozzuolanos* and *trass*, act even more energetically than the sands from the felspathic rocks; and when mixed with the pure hydrate of lime in proper proportions, they even communicate to it properties nearly similar to those of natural cements. On the other hand, sands containing plastic clay in its natural state are positively injurious; not only because the clay does not exist in them in a state able to form any stable compound with the lime, but also because it prevents the latter from performing one of its most useful functions in a mortar; namely, that of presenting a nucleus around which crystallisation could take place in the lime itself. At the present day it is believed that with the energetic cements a sharp, angular, crystalline sand, one whose chemical properties would be totally inert, is the best adapted for mortar making; with hydraulic limes the sands ought to possess the faculty of slowly forming new compounds with the hydrates of lime; and with rich limes, especially if they are required to be used in sea-water, sands exercising an energetic action on the hydrates must exclusively be used.

These remarks point to a rough practical subclassification of sands, into the classes of the *inert*, *slightly energetic*, and *decidedly energetic* sands; and Vicat, who was the first to call attention to this description of action, states that when sands are treated by acids and by lime-water they may easily be distinguished from one another. Thus the inert sands resist the action of acids, and are totally without action upon even boiling limewater. The slightly energetic sands yield in a trifling degree to the acids, and take up a small proportion of lime from the lime-water. The decidedly energetic sands are powerfully affected by acids, and they take up a large proportion of the lime presented to them in solution. Care must, however, be taken in the experiments on the nature of this class of materials to allow for the action of the acids upon the lime present in the sand; for all purposes connected with the formation of the insoluble silicate of lime and alumina by the reciprocal actions of the caustic lime and the sand, the calcareous matters of the latter will remain practically inert.

When considered with reference to their sources of supply, it may generally speaking be regarded that sea sands are purer and better fitted for mortar making than any other; provided always that the efflorescence of the muriate of soda they contain should not be likely to affect injuriously the character of the work. This would be the case with all internal decorations; and sea sand must therefore be carefully excluded from all ornamental structures. River sand is also very likely to contain the muriate of soda when obtained from the tidal portions of a stream, and in addition to this inconvenience there is almost a certainty that the river sand will contain a large proportion of nitrogenous elements, which would in a building give rise to the formation and efflorescence of the nitrate of lime, which in its turn would be fatal to any coloured decorations or paintings exposed to its effects. Pit sand is in fact the most generally fitted for building purposes; but care must be taken with it to secure that it should be free from argillaceous ingredients, and only that sand should be used whose grains are sharp and angular. The specific gravity of a sand is a *primâ facie* evidence of its goodness.

In brick and tile making, and in some processes of the higher ceramic arts, sand is occasionally used when the clay is, to use the workman's phrase, "too rich;" that is to say, when it is exposed to run together in the kiln in an irregular manner, in consequence of an excess in the proportion of alumina the clay may contain. A clay is considered, in fact, to be *rich* when the proportions of silica and alumina are respectively 60 and 40 per cent.; it is considered to be *poor* when those proportions are 80 and 20 per cent.; and according to the usage intended to be made of the clay a greater or less proportion of pure silicious sand must be added to the richer varieties. See Brogniart, 'Traité des Arts Céramiques.'

The very pure and perfectly white silicious sands which are found in Norfolk and in Alum Bay, Isle of Wight, used formerly to be raised in large quantities for glass making. The supply has been nearly exhausted; and latterly some of the best sands for this important branch of manufacture have been imported, in ballast, from Australia; rich ferruginous sands for steel making are also imported from New Zealand.

It may be desirable to add, that the fine sands charged with organic matters to be found in the embouchures of rivers, or in some bays on the sea-shore, are technically known by the name of silt, and that they are very rarely of any commercial value. Pit sands, or large deposits of sand in the interior, are occasionally found to be so charged with water as to remain constantly in motion, and are then called *running sands*. Under these conditions they form one of the most dangerous class of foundations, for if an escape should be found for the waters they may contain, the sands would in all probability be removed by them, and the foundations would be exposed to lateral displacement. The precautions to be taken in such cases are, if possible, to intercept the supply of water to the sand; if that cannot be effected, to keep it constantly charged; and, under either of those conditions, to isolate the immediate surface of the foundations in such a manner as to allow any movements which may be produced to take place vertically. Dry sand has, in its dry state, been often used in foundations instead of concrete; and if it be prevented from spreading laterally, that material is practically incompressible. It is also used for tamping round the charges of mines.

SAND; SANDPAPER. Many varieties of sand are used for manufacturing purposes. Stone-masons often use the scrapings of granite roads to aid the action of their stone-saws. Engineers frequently employ grindstone dust. River-sand and pit-sand are generally sharper or more angular than sea-sand; this difference leads to the selection of each for certain purposes. Kent sand is largely used at Sheffield, being fine and sharp; it is found an economical substitute for polishing powder for steel goods. *Sand-paper* consists of sand sprinkled over and cemented upon sheets of paper; it differs from emery-paper [EMERY] and glass-paper rather in the kind of substance used than in the nature of the action.

SAND VOLTAIC BATTERY. A form of battery sometimes used in connection with the Electric TELEGRAPH, consisting of a number of pairs of copper and zinc, with the cells filled with sand, which is kept moist by means of dilute sulphuric acid. This battery will remain active for a considerable time, and its activity can be renewed at pleasure merely by wetting the sand.

SANDAL-WOOD, RED, or Red Saunders Wood of Commerce. [PTEROCARPUS, in NAT. HIST. DIV.]

SANDARAC is a secretion from the *Callitris quadrivalvis*, a tree of enormous size, native of Marocco, and there called Arar. It exudes spontaneously from the bark, and concretes on the surface. It occurs in small, irregular, but rather elongated, seldom perfectly round tears, or in masses run together, of a light yellow colour, sometimes verging to brownish, of a dull hue externally, generally covered with powder, but when this is removed, semitransparent. It breaks easily with a conchoidal fracture and vitreous lustre. The powder is white, and forms the substance called *pounce*. By chewing, it forms a fine powder, which does not agglutinate, and has a faint balsamic taste. At ordinary temperatures it is without odour, but by the application of heat it easily melts and diffuses a strong though not unpleasant odour, resembling that of juniper or mastic. It is easily ignited. It is soluble to the extent of four-fifths in cold alcohol; and the insoluble residuum is easily soluble in ether, or, slowly and with difficulty, in boiling turpentine. The portion insoluble in alcohol is termed *Sandaracin*.

Sandarac is used for the preparation of varnishes, also occasionally for incense or pastiles, plasters, and ointments. The powder is rubbed on parchment to render it fit to be written on. Sandarac is sometimes used to adulterate mastic; and on the other hand, a resin obtained from the *Juniperus communis*, and another from *J. Oxycedrus*, are employed as a substitute for the genuine sandarac. In Sweden, lumps of resin which are found under ants' nests below the juniper bushes are called sandarac. The resin of the *Pinus dammara* is called French sandarac in commerce. Sandarac is incorrectly called a gum; it partakes more of the nature of a resin.

SANDEMANIANS. [SANDEMAN, ROBERT, in BIOG. DIV.]

SANDIVER. [GLASS MANUFACTURE.]

SANGUINARINE. ($C_{[illegible]}H_{[illegible]}NO_{[illegible]}$?) An alkaloid, found in the *Sanguinaria Canadensis*, but only partially investigated. It is a yellow insipid powder, insoluble in water, but very soluble in alcohol. It neutralises acids perfectly, forming red salts, which are soluble in water and very bitter.

SANHEDRIM, or SANHEDRIN (סַנְהֶדְרִין), the great council of the Jews, which consisted of seventy-one or seventy-two members, and decided the most important causes, both ecclesiastical and civil. The name is a corruption by the Talmudists of the Greek συνέδριον (*a council*). The rabbis attempt to find the origin of the Sanhedrim in the seventy elders who were appointed by Moses to assist him in his judicial duties (Numb. xi. 16); but this council was evidently temporary, and we hear nothing of it in the subsequent history of the Jews. (MOSES, in BIOG. DIV.; Michaelis 'On the Laws of Moses,' art. 50.) The exact time of the institution of the Sanhedrim is unknown; but there is no reason to suppose that it was earlier than the time of the Maccabees. There can however be little doubt that the Sanhedrim was an *imitation* of the seventy elders of Moses. The first mention of the Sanhedrim is in the time of Hyrcanus II., when Herod was tried before it. (Joseph., 'Antiq.,' xiv. 9, s. 3, 4.)

The Sanhedrim had a president (רֹאשׁ or נָשִׂיא), who was generally the high-priest, a vice-president (בֵית אַבִי דִין) who sat on the right of the president, and, according to some, a second vice-president (חָכָם). who sat on his left. The other members were:—1, *Chief Priests*, who are often mentioned in the New Testament and in Josephus, and who were partly ex-high-priests and partly the heads of the twenty-four classes of priests. 2. *Elders*; that is, the princes of tribes and heads of families. 3. *Scribes*, or men of learning. All chief priests were members of the Sanhedrim, but of elders and scribes only so many were admitted into it as were required to fill up vacancies. (Matt. xxvi. 57, 59; xxvii. 3, 12, 20, 41; Mark viii. 31; xi. 27; xiv. 43, 53; xv. 1; Acts iv. 5; v. 21, 27.) The Talmudists say that the tribunal had its secretaries and apparitors. Both Pharisees and Sadducees were found in it. (Acts v. 17, 21, 34; xxiii. 6.)

The Sanhedrim met at Jerusalem, and, according to the Talmudists, in a chamber within the precincts of the Temple, called *Gazith*, in which also their archives were kept; but, according to Josephus ('Bell. Jud.,' v. 4, 2; vi. 6, 3), in a room on the east side of Mount Zion, not far from the Temple. In cases of emergency, as in the trial of Christ, they met in the high-priest's house.

The causes brought before this tribunal were either appeals from the inferior courts, or matters which were thought of sufficient importance to come before them in the first instance: for example, the question whether a person was a false prophet (Luke xiii. 33), and matters which effected the whole state, a whole tribe, or the high-priest. The accused was brought before the tribunal, and witnesses were required to appear to support the charge. Either capital or minor punishments might be inflicted by the Sanhedrim; but under the Roman government its power was so far restricted that a capital sentence required the confirmation of the Roman governor, who was also charged with its execution. The stoning of Stephen was not done in accordance with the sentence of the Sanhedrim, but in a riot; and the execution of James and others by the high-priest Ananias (A.D. 64) took place in the absence of the Roman procurator, and is admitted by the Jews themselves to have been an illegal act.

Besides the Sanhedrim at Jerusalem, there were inferior courts in each town of Judæa, consisting of twenty-three members, to which the same name is sometimes applied. From these courts an appeal could be made to the Sanhedrim.

(Jahn, *Archäol. Bibl.*, th. ii., b. ii., § 186; Calmet's *Dictionary*; Lightfoot's *Works*; Winer's *Bibl. Realwörterbuch*, 'Synedrium.')

SANJAK, a word primarily signifying a standard, is also applied to a military division, the subdivision of an eyalet, into which the whole Turkish empire is divided: in this sense, it signifies, as much as is congregated under one standard. The commander of such a division is styled Sanjak, Sanjak Bey, or simply Bey, and the supreme general of all the Sanjaks of a province is styled the Beglerbey (commander of commanders). The word is found under the forms Sangiac and Sandschack, the French and German modes of rendering the Turkish word.

SANKHYA. [SANSKRIT LANGUAGE AND LITERATURE.]

SANSKRIT LANGUAGE AND LITERATURE. *Language.*—The Sanskrit is a branch of the Indo-Germanic family of languages. Of all these languages it is that which approaches nearest to the primitive type; and by the originality, purity, and abundance of its forms, is peculiarly calculated to throw light on the obscure laws of the formation of language. Being also possessed of a rich literature, and the whole of its materials having been fully treated of by native grammarians, it was no sooner introduced to the learned of Europe than it gave rise to a new philological science, that of comparative grammar, and led to the conclusion that the ancient Persian, the Armenian, the Greek, and the Latin, formed but one language with the German, the Lettic, the Slavonian, and even the Celtic, each of these languages affording the most extraordinary illustrations of the others.

The Sanskrit was introduced into India when the Brahminical race obtained possession of the country (A. W. von Schlegel, 'De l'Origine des Hindous,' in the 'Trans. Roy. Soc. Literature,' ii., 2, 405, &c.; Chr. Lassen, 'Indische Alterthumskunde,' i. 515, 531, ff.; M. Müller, 'History of Ancient Sanskrit Literature,' 1859, p. 12); and having driven out the languages of the aborigines of India, which are now only spoken in the Southern Deccan, as the Telugu, Tamul, Canarese, and, others, and by some detached tribes, chiefly in the Vindhya mountains, for example, the Gonds and Khonds (Lassen, l. l. i., 366, ff.; M. Müller, 'On the Classification of the Turanian Languages,' p. 169, ff.; R. Caldwell, 'Compar. Grammar of the Dravidian Languages,' 1856, p. 8, ff.), has spread over the extensive tract of country between the Himalayas, the Indus, and the Kistna. Within these limits it has had a history of its own, and has passed through various changes. It appears in its most ancient form in the Vedas, about the 15th century before Christ, and in that state is very nearly related to the Zend, the ancient language of Persia, and contains many forms and words which have become obsolete. The classical Sanskrit, on the contrary, having once become fixed, has, for about 3000 years, partly as a living language and partly as a learned one, retained the same structure, with the mere exception of difference in style, and a few archaisms, which only occur in the most ancient works.

Prakrit dialects.—Out of the Sanskrit, however, even in comparatively early times, dialects arose, which gradually became still farther removed from the original and from each other; and from these dialects those of the languages now spoken in India are derived, which do not belong to the aboriginal languages mentioned above. There is a law, however, which pervades the whole of those *Prâkritas*, that is, derivative languages, as they are called by the Indian grammarians, in contradistinction to the *Sanskrita*, or that language which is regularly and grammatically constructed (A. Weber, 'Vorlesungen über indische Literaturgeschichte,' 1852, p. 168); and it is worthy of remark, that this law is precisely the same as that according to which the Romance language, the Italian, the Spanish, and the French, have grown out of the Latin. There is the same softening, the same assimilation, and the same exclusion of the harsher sounds, the same weakening of the forms, the same substitution of particles for cases, and the same periphrastic conjugations.

The oldest of these dialects, and that which deviates least from the Sanskrit, is the *Pâli*, which has become the sacred language of the southern branch of the Buddhists, who, when they abrogated the institution of castes, required a language which, at least for works not strictly scientific, should not be exclusively understood by the privileged classes. Having originally been carried by the Buddhists from Northern India to Ceylon, the Pali has continued to exist in that island, as well as in Burmah, Siam, and Kamboja, and possesses a copious literature. (Burnouf and Lassen, 'Essai sur le Pali,' Paris, 1826; Clough, 'Pali Grammar,' Colombo, 1824; 'Journ. Ceylon Branch R. As. Soc.,' 1847, No. 3, p. 189, ff.; Pallegoix, 'Gramm. Linguæ Thai,' Bangkok, 1850, p. 181, ff.) Different from the Pali is the *Gâthâ*, or ballad dialect, which appears only in the poetical portion of the Buddhist literature of Nepal ('Journ. As. Soc. of Bengal,' xxiii. p. 604; 'Lalita Vistara,' ed. by Rajendralal Mittra, Calc. 1853, ff.) The language which, in a peculiar sense, is called Prakrit, properly *Mahârâshtrî* (for its local origin is to be sought in the country of the Mahrattas), differs little from the Pali; it is used by the Jains. The *Mâgadhî* and the *Saurasenî*, the former originally spoken in Behar, and the latter on the banks of the Jumna, are only a little farther removed from the Sanskrit. (Lassen, 'Institutiones Linguæ Pracriticæ,' Bonn, 1838; J. Muir, 'Original Sanskrit Texts,' vol. ii., p. 138, ff., where the different opinions on the origin of the Prakrits are set forth and examined.) In addition to these there are numerous more modern dialects, among which we shall only distinguish the Vrajabhâshâ (Brij Bhakha), on account of the excellence of its poetical literature, and as being the parent of the Hindustani.

The formation of the Prakrita languages out of the Sanskrit flowed naturally from the character of the parent tongue, and this tendency is manifested even in the earliest shape of the Sanskrit. This appears, to take a single instance, in the substitution of the *ch* and *j* (the Italian *ci* and *gi*) for the original *k* and *g* (just as the Italian *gielo* is formed from *gelu*). In like manner, it was perfectly consistent with the character of the classical Sanskrit to adopt the verbal forms of the Prakrit, and to retain them together with the legitimate and settled forms, which is a proof that the two languages must have co-existed for a long period.

The Pali appears as a perfectly-formed language in the Buddhist works carried to Ceylon, which we cannot fix at a later date than the 4th century before Christ (Lassen, 'Ind. Alt.,' ii. 489; Muir, l. l. p. 65-107); and the Mâgadhi dialect has been found distinctly recorded, in the middle of the 3rd century before Christ, in the inscriptions of King Asoka, which were first deciphered by the late Mr. J. Prinsep ('Jour. Asiat. Soc. Beng.,' 1837, pp. 566, 794, 963), whose translations were subsequently revised by Prof. H. H. Wilson ('Journ. R. Asiat. Soc.,' for 1849, vol. xii., p. 153-251, and vol. xvi., p. 357, ff.); and a portion of them were lastly examined by M. E. Burnouf ('Le Lotus de la bonne Loi,' Paris, 1852, p. 652-781), whose researches on the whole question may be considered as conclusive (Lassen, 'Ind. Alt.' ii. p. 215-229). A Prakrit language likewise appears on the coins of the

Greek kings found in Caubul, and near the Indus, which have been deciphered by Prinsep, Lassen, Wilson, and E. Thomas. (J. Prinsep, 'Essays on Ind. Antiquities,' Lond., 1858, 2 vols.) Many of the names also which have been transmitted to us by the Greeks are Prakrit; that of the Deccan, for instance, in the Periplus of the Erythræan Sea, Δαχιναβάδης, does not correspond to the Sanskrit *dakshinâpatha*, but strictly to the Prakrit *dakkhinabadha*. Hence it follows, that in the last five centuries B.C. the Prakrit must have become completely the language of the people; and indeed the dramas which were written about this time show the relation of the two languages in the most distinct manner, the men speaking Sanskrit, and the women and inferior characters Prakrit; which is likewise a proof that the Sanskrit was actually a living tongue, and was used in conversation by all educated people. This is proved by many other circumstances; and it would be a great mistake to view the Sanskrit as having become from this time merely a learned language. On the contrary, it was in vogue at the court of Cashmere as late as the 12th century A.D. (Lassen, l. l., iii., p. 1082, ff.), and probably in the small independent courts of Malwa even in the 14th and 15th centuries. It is consistent with all that we know, that the language should be in a different condition in the different provinces of India, The Mohammedan conquest, however, gave the final blow to it, and it is now used only in learned disputations in the colleges of the Brahmins.

Literature.—The Sanskrit literature begins with the Vedas, and is founded entirely upon them. [VEDAS.] The rest of the literature may be divided into the poetical and the scientific. The poetical literature may be referred to two distinct periods, one of which is chiefly distinguished by the composition of the great epic poems, and the other may be characterised as the period of artificial poetry. In the former, the interest is a national one, and arises from the subject; in the latter, it depends upon the form.

Epic Poetry.—We possess the epic poetry only in its most perfect state, and consequently its origin is involved in obscurity, and must be looked for among the rhapsodists, whom the 'Râmâyana' presents to us pretty much in the same character as that in which they appear among the later princes of India. The materials of the epic consisted primarily of the genealogies of the princely families whom the rhapsodists served, and next, of certain prominent events in the family history, which were at first sung separately, but afterwards incorporated in the genealogy itself. It is possible therefore that there may have been as many epic poems as there were princely races. In the lapse of time, however, all these poems have been lost except two, which are indebted for their preservation partly to their poetical merit, and still more to the interest of the subject: these are the 'Râmâyana' and the 'Mahâbhârata.' But even these have undergone many important alterations since they came from the hands of the authors; in fact, they have been entirely remodelled in accordance with the interests of the priesthood, by the addition of those parts in which Râma and Krishna, originally no more than mortal heroes, appear as incarnations of Vishnu; these additions, however, have been so loosely attached, that they might easily be separated without detriment to the whole. In the 'Mahâbhârata,' the object has been kept in view of including in one collection the whole cycle of tradition; and as the epic poems were intended for the instruction and amusement of the warrior caste, not only was everything added which could increase their reverence for the Brahmins, but there are whole books, of considerable length, in which their systems of cosmogony, philosophy, and law are explained in a popular manner.

The Râmâyana.—The subject of the 'Râmâyana' is the descent of Vishnu, for the purpose of averting the threatened destruction of the whole world by the prince of the demons, Râvana. Râma, the son of Dasaratha, king of Oude, was brought up by wise Brahmins, especially Visvâmitra; while yet very young he overcame the demons in several battles, and by his superhuman strength obtained the hand of the beautiful Sitâ. He was about to be appointed successor of his aged father, and to be his partner on the throne, when the plan was frustrated by a court intrigue, and he was compelled to wander abroad as an exile. With Sitâ and his brother Lakshmana, who also participated in the divine nature of Vishnu, he dwelt in the inhospitable wilds of the Deccan, in the forest of Dandaka, at the sources of the Godavery. This course of events was necessary in order to bring him and Râvana together, for here Râma made himself terrible to the demons, and having mutilated, among others, Sûrpanakhâ, the sister of Râvana, the demon prince, partly out of revenge for this outrage, and partly inflamed by violent love for Sitâ, carried her off, and brought her in safety to his residence at Lankâ (Ceylon). Râma and Lakshmana, unacquainted with the abode of Râvana, wandered about in the peninsula in search of Sitâ. The ape-king Sugriva, who had been dethroned by his own brother Bâli, was restored to his kingdom by Râma, and from a feeling of gratitude sends out a host of apes for the purpose of finding the abode of Sitâ. The ape Hanumân at length discovers it, passes across the strait, seeks out and speaks with Sitâ, sets fire to Lankâ, and conveys the intelligence to Râma, who proceeds with the whole army of apes to the southern point of the peninsula, when an enormous bridge is formed by throwing mountains into the sea. As the army is about to march upon the island, Râma is encountered by Vibhishana, Râvana's brother, and a Titanian conflict commences, the description of which is one of the most admired parts of the poem: but the demons are at length subdued; Râvana falls by the hand of Râma; and Sitâ is recovered, and having been found pure, as well by the ordeal of the gods as by the word of Brahma himself, she is again united to Râma, who, returning to Ayodhyâ, receives from the hand of his brother Bharata the dominion to which he is entitled.

These are the contents of the first six books, and here the poem terminates. But there is a seventh book, which is obviously a later addition, and consists of matters which are entirely independent of the former narrative: Sitâ is again separated from Râma, and bears two sons, Kusa and Lava, to Vâlmiki. After her innocence has been again established, she is carried away by the goddess Earth. Kusa and Lava have learned the poem from Vâlmiki, its mythological author, and recite it at a great sacrificial festival. whereupon Râma acknowledges them as his sons. This is obviously an etymological myth derived from the Sanskrit name of the rhapsodists, *kusîlava*. This agrees with the present introduction to the first book, in which the origin of the poem is told in the same way, and both parts must therefore be regarded as additions made by the last editor. That the 'Râmâyana' has undergone many other alterations, may easily be shown. It contains, in some parts, many things which point to very ancient times, and customs introduced at a later period are not even alluded to; as, for instance, the burning of widows, which was practised in the age of Alexander. In other parts circumstances are referred to which bring us as far down as the 2nd century A.D., the names of comparatively recent nations being mentioned: for instance, the Huns.

The time of the composition of the poem cannot therefore be ascertained with any further degree of accuracy; and it is still a controverted question whether the Mahâbhârata or the Râmâyana, in the form in which they have been handed down to us, has the better claim to antiquity. It is more easy to determine what historical fact forms the foundation of it. This is evidently the introduction of the Brahminical worship and civilisation into the peninsula, the wild aborigines of which, as being the opponents of Brahminism, are made to appear in the character of demons. The apes must represent another and a less hostile race, whom the Brahmins made use of in order to overcome the ruder tribes. This fact is indicated by another circumstance in the poem: the guide of Râma is the hermit Agastya, to whom tradition ascribes the conversion and cultivation of the Deccan, and who even now shines, according to a sublime symbol, as the radiant Canopus of the South.

The 'Râmâyana,' since the last recasting of the poem, has undergone several revisions, four of which are known to exist (Weber, 'Verzeichniss der Berliner Sanskrit-Handschriften,' 1853, p. 119), which differ from one another less in substance than in style and arrangement. That which contains the oldest and the best text is confirmed by commentaries; a critical edition of it to the end of the second book, accompanied by an elegant Latin translation (as far as ii. c. 20), by A. W. von Schlegel, appeared at Bonn, 1829, 3 vols. The same recension is represented also by the Oxford manuscript ('Catal. Cod. MSS. Sanscriticorum,' 1860, vol. i., p. 6). An edition, based on a different text, was commenced by Carey and Marshman (Serampore, 1806-10, 4 vols. 4to); it goes as far as iii. c. 63, and contains also an English translation. The whole Râmâyana, according to the Bengali or amplified recension, was edited, with an Italian translation, by G. Gorresio (Paris, 1843-58, 10 vols.); there is also a French translation of the same by M. H. Fauche (Paris, 1854, ff., 9 vols.)

Mahâbhârata.—For the second of the two great epic poems, see the article MAHÂBHÂRATA.

Laws and Jurisprudence.—Besides the book of Manu, which has obtained the highest reputation among the 'Dharmasâstras,' or law-codes [MANU], there were many similar books, which were likewise referred to sacred mythological personages, as Vishnu, Vrihaspati, Nârada, and others. The principal sources from which they draw are the 'Sâmayâchârikasûtras,' a class of works belonging to the last period of the old Vaidic literature, in which the laws of caste, the rules of discipline, the occupations of kings, householders, &c., and the adminstration of justice, are accurately detailed. (M. Müller, 'History of Anc. Sanskrit Lit.,' p. 134.) There was a considerable number of these works, according to the different Vedas or Vaidic schools to which each professed to belong, the names by which they went being either those of their authors or of the families in which they were first current. These names were retained by the compilers of the Dharmasâstras; and the law-book of Âpastamba, for example, is distinctly traceable to the Sâmayâchârikasûtras which bear the same name. The subjects of which the Dharmasâstras treat are these three: *Âchâra*, comprising domestic and civil observances and all matters relating to caste; *Vyavahâra*, of the duties of kings and the administration of justice; and *Prâyaschitta*, of the civil consequences of caste-defilement, or other sinful actions, and of the way how to avoid those consequences by purification and penance. This threefold division is strictly adhered to in the law-code of *Yâjnavalkya* (edited by Prof. Stenzler, in Sanskrit and German, Berlin, 1849), the first after Manu in point of time and authority. In the other law-codes (eighteen of which were printed, together with that of Yâjnavalkya, at Calcutta, 1845, ff.), prominence is given to one or other of those three divisions. In the laws of Vishnu, for example, the judicial portion is very meagre, whereas the first and third are more fully treated than either in Manu or Yâjnavalkya. The laws of Daksha and Parâsara contain nothing about civil law at all, but so much the more about purification, penance, &c. These minor *Smritis*, as they are also called (*Smriti* means immemorial usage), are for the most part of small extent, and touch upon civil law only incidentally; they are, moreover, although received in common by all the schools, no longer final authorities, even where they do treat of law. For that purpose recourse must be had to the Commentaries and Digests. "Some of the former are merely explanatory of the text, but others are regarded as final authorities; and these latter, together with the Digests, form the immediate groundwork for the opinions of lawyers in the respective schools where the doctrines they uphold may prevail. Many of the Commentaries on the Smritis —such, for instance, as those on Manu's institutes—are not considered to be final authorities, any more than the Smritis themselves; but others again which, by the introduction of quotations from other writers, and by interpreting and enlarging on the meaning of the author, partake so far of the nature of general Digests, are referred to for the final decision of questions. The 'Mitâksharâ' (printed at Calc., 1812) is a remarkable instance of this; since, though professedly only a commentary on the Smriti of Yâjnavalkya, it is consulted as a final authority over the whole of India, with the exception of Bengal alone." (Morley, 'The Administration of Justice in Brit. India,' 1858, p. 213.) In the Bombay presidency are Nîlakantha's 'Mayûkha,' and in the Deccan the 'Smritichandrika' by Devandabhatta, of equal authority with the 'Mitâksharâ;' whereas in Bengal the latter has been entirely superseded by the 'Dâya Bhâga' (on the laws of inheritance) by Jîmûta Vâhana. For the modern law literature in Sanskrit, which is very extensive, consult Wilson's preface to Macnaghten's 'Principles of Hindu and Mohammedan Law,' London, 1860; Morley, 'The Administration of Justice in Brit. India,' p. 213–36; Sir A. Steele, 'Summary of the Law and Custom of Hindu Castes,' Bombay, 1827, p. 1–29; Borradaile's Introduction to his translation of the 'Vyavahâra Mayûkha,' Surat, 1827.

Purânas.—The Purânas, if we regard the form, must be classed with the ancient epic. They are voluminous collections of legends and traditions, written to elucidate the origin and history of some particular holy place or a certain sect, and to be read to the people for their instruction at the great festivals. They all begin with a cosmogony, to which they add the genealogy of the gods and the development of the periods of the world, as well as unconnected historical traditions, so as to form a fabulous chronology; and thus they come down to the history of the sacred place to which they are especially dedicated; they then conclude with the miracles, and so forth, which have been performed there. As they were intended to be read publicly, they are of course used as vehicles for conveying such instruction as the people might be presumed to require. They contain, therefore, not only recommendations to devotion and faith, and copious representations of the religious usages and customs, but also systems of the sciences which were known to the natives of India, as astronomy, mensuration, and jurisprudence, which are different in each Purâna, according as the priesthood of a temple belonged to this or that sect, or to this or that school of philosophy, astronomy, or law. In their present form, the Purânas are decidedly very late compositions, but the elements out of which they have been constructed belong to very different periods. They themselves refer to still older sources, and all the circumstances combined lead to the conclusion that there must have been another set of Purânas, which are now lost, and of which the present are an altered form or an imitation. Their great similarity, as well in their general structure as in particular parts, shows that they must have been formed upon one type, and that one very ancient, and that the differences which they present arise from the difference of object, according as they emanated from this or that place, or this or that sect. The older authorities actually give definitions of the Purânas which do not apply to them as they exist at present, and which presume an older form. It may even be asserted that entire portions of them must originally have belonged to the Vedas. In their present shape, none of the Purânas can be referred to an earlier date than the 9th century A.D., and the greater part of them are much later, and closely connected with the formation of the more recent sects. Though they are metrical compositions, they have no pretensions to poetic merit, if we except the 'Bhâgavatapurâna,' which was probably written by Vopadeva. They are arranged according to a certain canon, and are eighteen in number, under the titles of Brahma, Padma, Brahmânda, Agni, Vishnu, Garuda, Brahmavaivarta, Siva, Linga, Nâradîya, Skanda, Mârkandeya, Bhavishya, Matsya, Varâha, Kûrma, Vâmana, and Bhâgavata. Besides these, there are said to be eighteen *Upapurânas*, or secondary Purânas, only a few of which, however, are known. There are many others, not included in this canon, which are called *Sthalapurânas*, or local Purânas, and are of little importance. Several of these have been described by Prof. Wilson, in the 'Catalogue of the Mackenzie Collection' (Calc., 1828). The Purânas have been chiefly made known to us by the analyses of Wilson, in the 'Asiatic Journals' of Calcutta and London; by his translation of the 'Vishnupurâna,' London, 1840, 4to; and by Burnouf's edition of the 'Bhâgavata,' 3 vols., Paris, 1840-47, fol., as far as B. ix. Two complete editions have appeared in India, one at Calcutta, 1830, and the other at Bombay, 1839, both with the scholia of Sridharaswâmin. An edition of the 'Mârkandeyapurâna' was commenced at Calcutta in 1855.

Artificial Poetry.—Sanskrit poetry received a new character, and one essentially different from that which we have been just considering, in consequence of the revolution which took place in Sanskrit literature about the first century before Christ. Instead of the popular and national character which appears in the two great epic poems, it now assumed an artificial form, and became the poetry of courts and princes. How this was effected cannot be historically shown, for the various steps of the transition are lost, and the new poetry appears at once in its perfect state. It is, however, quite obvious that the two great epic poems had long been completed and were in universal repute. The new poetry is poor in invention, and drew its materials from the former. Its whole merit consists in what may be called style. Even the epic versification is for the most part neglected, and lyric metres are substituted for it. This is not merely a difference in external form, but it is connected most intimately with the mode in which things are viewed by the Indians, who, being devoted to contemplation, delight to work up their poetical materials not so much into a continuous action, as into a series of single situations. Each of these situations is exhibited in a single stanza or strophe, which forms an independent whole, and is not connected with the others either grammatically or metrically. This peculiarity is as obvious in the epic as in the lyric and dramatic poetry.

The *new Epic poetry* begins with Kâlidâsa, to whom two works of this class have been ascribed, 'Kumârasambhava' and 'Raghuvansa.' [CÂLIDÂSA, in BIOG. DIV.] They are written in a style worthy of imitation, and their whole character shows that they are older than the others, from whose superfluities these early works are free. The materials belong to the mythic cycle of the 'Râmâyana.' The disposition to describe rather than to narrate is exhibited as well in single passages as in the whole. Whenever an opportunity occurs, long descriptions are introduced, such as pictures of natural objects, to which the old epic poetry was also inclined, but more sparingly, and only incidentally: here, however, they encumber the whole progress of the action. This is much more the case in the two following poems, in which the descriptions appear to the poet to be so important that he seems to have undertaken the works only for the purpose of introducing them. These works are the 'Kirâtârjunîya,' or "the battle of Arjuna with the Kirâta," by Bhâravi, and 'Sisupâlabadha,' or "the death of Sisupâla," by Mâgha, both founded on episodes of the 'Mahâbhârata.' They are classical compositions, and elaborated with the utmost nicety; but the art of the poet degenerates into a mere play upon words. There are verses which may be read forwards and backwards, and upwards and downwards; others in which only one and the same consonant is used (as "Sis. 19, 114, 'dâdado duddaduddâdî dâdâdo dûdadîdadoh duddâdan dadade dudde dadâdadadado' dada," which indeed is not very clear, but still has a meaning), or two consonants or more are used. These poems were printed at Calcutta, 1814, 1815, and again 1848, with the commentary of Mallinâtha. The 'Bhattikâvya,' written in the 5th or 6th century, in Vallabhî, the chief town of Guzerat, narrates the history of Râma, but only for the purpose of elucidating the more rare grammatical forms, every canto being written in a certain tense, &c. (Published at Calcutta, 1828, with two grammatical commentaries.) The 'Nalodaya,' falsely ascribed to Kâlidâsa, gives the history of Nala out of the Mahâbhârata, but only to show the skill of the poet in an incessant play of words and rhymes. (Edited by F. Benary, with the commentary of Prajnakâra, a Latin translation and notes, Berlin, 1830; and by W. Yates, with a metrical translation, grammatical analysis, &c., Calc., 1844.) The most artificial of all these poems is the 'Râghavapândavîya' of Kavirâja. (Published at Calc., 1854, with a commentary by Premachandra Tarkavagîsa.) It is written with such a purposed double meaning, that the same words give us the histories of Râma and also of the sons of Pandu, which is only possible in consequence of most of the Sanskrit proper names having also a perfect appellative meaning, so that in the one history the proper names must be dropped, and in the other the appellative meanings. We shall mention in the last place the 'Naishadîya' of Srîharsha, king of Cashmere in the 12th century. It treats of the marriage of Nala, and nothing else, in twenty-two long cantos, written throughout in a very artificial manner, which however makes it a great favourite among the Indians. The descriptions in this poem exceed in length and number all reasonable bounds, and there can hardly be said to be any action at all. It was printed at Calcutta in two volumes, the first with the commentary of Premachandra, 1836, and the second with that of Nârâyana, 1855.

Lyric poetry, in the proper sense of the term, did not exist among the natives of India at this period, for even here their fondness for description has taken the place of everything else, and, instead of lyric poetry, we have the epigrammatic, didactic, and descriptive. Even their amatory poetry appears to be not so much the expression and effusion of feeling as a studied and laboured display of situations. An agreeable work of this description, the 'Amarûsatakam,' consists of 100 single small poems, each of them being nothing more than a stanza which represents an amatory scene, and which we should call an epigram. (Published at Calcutta, 1808.) To this class belongs also the 'Sringâratilaka,' which has been improperly ascribed to Kâlidâsa. To these must be added the first book of the 'Centuries' of

Bhartrihari, while the two other books contain didactic poetry. The work has been ascribed to the brother of King Vikramâditya, who lived in the 1st century, B.C.; and we have the high authority of Prof. Lassen ('Ind. Alt.,' ii. 803, 1161), for the probability of this assertion being correct. (First edited at Serampore, with the 'Hitopadesa,' 1804; and at Berlin, 1833, by Bohlen.) Among the poems properly called descriptive, by far the best is the 'Meghadûta,' certainly a genuine work of Kâlidâsa, which in a style of the utmost elegance and simplicity, describes the course of a cloud over a part of India, the residence of the god of riches and of the wife of a demigod who had been banished to earth [CÂLIDÂSA, in BIOG. DIV.]: the poem is put in the mouth of the demigod himself. The value of this poem as a work of art lies chiefly in this, that every single external phenomenon receives a spiritual meaning, and all nature seems to be endowed with life. It is very different in the later poems of this class, which are properly only rhetorical centos and collections of all the current expressions and comparisons of previous poets. A work of this kind on the seasons—a subject indeed which is frequently introduced in the epic poems, the 'Ritusanhâra'—has been improperly ascribed to Kâlidâsa. (Printed at Calcutta in 1792, and at Leipzig in 1839.) A similar one on amatory common-places, 'Chaurapanchasikâ' (in Bohlen's 'Bhartriharis'), is bombastic and spiritless. This branch of literature must have been very rich, and many of the older works have undoubtedly been lost. Most of those that are extant, including the 'Meghadûta,' 'Ritusambâra, 'Gîtagovinda,' 'Nalodaya,' 'Bhartrihari,' 'Amarûsataka,' are contained in Hœberlin's 'Sanskrit Anthology,' Calc., 1847.

The Drama.—According to the tradition of the Hindus, the Indian drama had its origin in very ancient times, the rules concerning it having been communicated by Brahmâ himself to the hermit Bharata (which means the supporter, bard, actor). Though we are unable to trace it historically, as we know it only in its perfected form, still we may perhaps not be far wrong if we fix about the end of the 4th or the beginning of the 3rd century B.C. as the most probable time when it received its first development. An examination of the technical terms employed in the Hindu drama favours the supposition that, in its first stage, it consisted in dances, accompanied by gestures and songs, in which some historical event was celebrated; that then the persons themselves who were the subjects of those songs were represented by the singers; and that, lastly, the regular dialogue took the place of the dancing and singing. (Lassen, 'Ind. Alt.,' ii. 502-5; Weber, 'Ind. Lit.,' 184, ff.)

Such performances are still retained in their original form at the festivals of Rama and Krishna. The characters of the pieces come forward one after another, and sing a song accompanied with gesture. It is obvious that a considerable time must have elapsed before so simple a beginning could have grown into a regular dialogue and a complicated action, in which mythological and domestic, and even historical, materials are interwoven into the representation. But the Indian drama, even in its highest state, is still in a low condition. Among the Greeks and the moderns individual action and the collision of moral powers form the moving forces of the drama; but that of India is rather a series of events and situations which are exhibited in succession to the spectator. The distinction between tragedy and comedy is unknown, and the Indian drama most nearly resembles the modern opera. The Indian dramatists have not yet arrived at the discrimination of character; the heroes and heroines resemble one another more or less in all their dramas; and the species rather than the individual is everywhere represented. There are also standing characters, such as the *vita*, who is the *gracioso* of the Spanish stage, and the *vidûshaka*, who is the clown of the old English. This latter personage is always the necessary attendant of the principal hero, whom he parodies, and whose ideal wishes he contrasts with his own practical views, and these contrasts are often very strongly coloured. The strict rules of the Greek drama are unknown to that of India, and even in many external particulars it is comparatively unfettered,—as, for instance, in the number of acts, of which there may be as many as ten. In the form there are two peculiarities which especially require notice: first, the interchange of dialects in the dialogue, which is in general skilfully and delicately managed, and gives us a high idea of the social cultivation of the Indians in those remote times (it has already been observed that the heroes speak Sanskrit, but that the women and inferior characters speak various dialects of Prakrit); and, second, the interchange of prose and verse. The dialogue is entirely in prose, but is interspersed with verses in the lyric metres, always of the descriptive character before mentioned, which sometimes exhibit a feeling or a situation, and sometimes describe something which cannot be actually represented on the stage, as the rapid travelling of a vehicle. As to the scenic representation, our information is limited. It may be inferred from their rhetorical books that great care was bestowed on the declamation and the costume, but the stage-management and the decorations appear to have been very rude. Still the dramatic literature of India is beyond all doubt much richer than we are yet aware of. The names of about 60 pieces are known to us, of which 13 have been edited, and we are indebted to Professor Wilson for longer or shorter notices of 20 others. ('Theatre of the Hindus,' 2nd edit., Lond., 1835.) Fortunately, the pieces which have been edited are sufficient to enable us to take a rapid view of all the eras and divisions of this branch of their literature.

The classic age of the Indian drama may be divided into three periods: the first includes the time before Kâlidâsa, of which only one piece remains, 'Mrichhakati,' 'The Toy-Cart,' by King Sûdraka (who probably lived about the end of the 1st century A.D.). It is easy to discover that this piece belongs to the early period of art: the poet has to contend with materials which he does not well know how to handle. There is a certain clumsiness in the management of the acts and scenes, and the excess of descriptive poetry is fatiguing, a whole act, for instance, being occupied with the description of a storm. In other respects it is strikingly original, and contains few of the common-places which occur in the other poets; the different dialects of the Prakrit also are more closely amalgamated than in the other pieces. To Europeans this drama is particularly valuable, as giving a representation of Indian manners which cannot be found in any other work. Though it is the only remaining piece of this period, many others must have existed before Kâlidâsa; for the general theory of the dramatic art was already perfected, which is obvious from his frequent allusions to it.

The second period begins with Kâlidâsa (about the middle of the 2nd century A.D.), under whom the Indian drama reached its highest degree of perfection. We have two pieces by him, 'Sakuntalâ' and 'Vikramorvasi' [CÂLIDÂSA, in BIOG. DIV.], of which the last has been denied to be his; but, to judge from the style and spirit, it must certainly be ascribed to him. Kâlidâsa is indeed the most perfect of the Indian dramatists, for in his pieces we have the utmost elegance of style, without anything over-laboured or artificial; the development of his plot is natural and well considered; and there is always a correct relation of parts. As to his poetical merit, Europeans have been enabled to form a judgment from the graceful translation of his 'Sakuntalâ,' by Prof. M. Williams (Hertford, 1855).

The third period begins with Bhavabhûti, at the commencement of the 8th century, whose era is established by a passage in the 'Chronicle of Cashmere' (iv. 144). Dramatic poetry had now undergone a great change, the historical progress of which we are unable to describe for want of the necessary evidence. Bhavabhûti was a learned poet, who constructed his works entirely according to the dramatic theory of previous writers. He has accordingly a very high reputation in India, but he has all the faults consequent on the direction thus given to his genius. With all his poetic talent, he is deficient in true dramatic spirit; his results are laboured, and there is always a display of art and a want of nature. Description is with him always in excess, and the diction of single passages is not only too artificial, but also pompous, and to Europeans therefore not without difficulty. There are three pieces of his; one in which a domestic subject is treated, the loves of Mâlati and Mâdhava, and two others taken from the cycle of traditions of the Râmâyana, 'Mâhâviracharitra,' and 'Uttararâmacharitra.' The last is most free from the excessive elaboration of style.

As specimens of dramas of intrigue in the Indian style, 'Ratnâvali' and 'Mâlavikâgnimitra' are worthy of notice. The first was written in the 12th century by some poet at the court of Sriharsha, king of Cashmere; the other was long prior to Bhavabhûti, probably by Kâlidâsa himself. The plan of these pieces is not unskilful, and the language is easy and graceful; the subject itself warning the poet to avoid a highly ornamental style. Another kind of interest belongs to the 'Mudrârâkshasa' of Visâkhadatta; the exact time to which this drama belongs is unknown, but it is certainly after Bhavabhûti; the matter is historical, namely, the history of Chandragupta, the Sandrocottus of the Greeks. In the deficiency of historical information, even such a tradition is important, and the piece also throws much light on the politics of the Indian courts. As a drama it is not of much value; it is mostly written in prose. The 'Prabodhachandrodaya' ("the rising of the moon of reason") is of a character quite peculiar: it is an allegorical play, written by Krishnamisra in the 11th century, in which purely abstract ideas, as virtues, passions, and crimes, are personified and act, and by means of whom the Vedânta philosophy at last celebrates her triumph. Setting aside the strangeness of such a work of imagination, it must be admitted that the author has performed his task with great skill.

It was much later before the peculiar species of drama made its appearance which is called *prahasana* (*comedy*, or rather *farce*). The pieces are short, and are valuable as exhibiting an entirely new kind of literature. They are bitter satires, as unrestrained as those of Aristophanes, and aimed at the deep state of degradation into which the Indians had sunk, chiefly through the corruption of the Brahmins. The Dhûrtasamâgama' ("the assembly of rogues") is a playful wrangle between a Brahmin and his scholars about a courtesan. The piece has the merit of parodying in a happy manner the bombastic style of Bhavabhûti, which is a proof that even in India there were critics who were opposed to the common opinion, and who ridiculed the perverseness of the general taste. This little piece belongs to the end of the 15th century. (Published in Lassen's 'Anthologia Sanscritica,' Bonn, 1838.) The later dramas confine themselves entirely to mythological subjects. The greater number of the sixty pieces before mentioned belong to this class. An imitation of the 'Prabodhachandrodaya' is the 'Chaitanyachandrodaya,' a drama in ten acts by Kavikarnapura, in which the life and mystical reveries of the philosopher Chaitanya are celebrated. It dates from the 16th century. Amongst its faults are a profusion of alliterations, and a gorgeously ornate style: but, regarded as an ideal drama—a series of tableaux vivans, presenting faithful portraitures of the adored object of a large body of enthusiasts—the work will always command the esteem of the lovers of literary worth. It was published at Calcutta, 1854.

The 'Gîtagovinda' of Jayadeva, written in the 12th century, is entirely different from the works already described. It is a poem intended for performance at a festival of Vishnu, and belongs to that class to which we ascribed the origin of the drama. It exhibits the separation of Krishna from his wife Râdhâ, his love adventures with the shepherdesses, and the reconciliation of the husband and wife, in a series of songs, which are connected and introduced by strophes which describe the situations. The strophes were intended for recitation, the songs to be sung. This is therefore the only Sanskrit poetry which we possess that can properly be called lyric. But the songs are entirely written on the model of the Prakrit songs, which alone appear to have been intended for singing, and they have throughout the Prakrit metres. The word *govinda* itself is a Prakrit form of the word *gopendra*, "the master of the shepherdesses," which is one of the titles of Krishna. The scholiasts explain the poem in a mystic sense: Krishna is the soul, which emanated from God, with whom it was originally in union, but was drawn down from him by sinful objects (the shepherdesses); at length, however, full of desire for its original purity, it returns to God. In fact, the author himself, in certain passages, seems to intimate that he had some such deep meaning in view: and perhaps we may here find indications of the influence of the mystic poetry of Persia. (Printed at Calcutta, 1806; and there is an excellent edition by Lassen, Bonn, 1836, 4to.)

Narratives.—As the old epic poems were especially designed for the warrior-caste, so the Vaisyas, the third class, have a literature of their own, the *narrative*, of which the first which requires notice is *Fable*. In the 'Râmâyana' and in Manu there are allusions to well-known fables, and others are related in the 'Mahâbhârata.' The two chief works of later times, but which are still of some antiquity, are the 'Panchatantra' and 'Hitopadesa.' [PILPAY, in BIOG. DIV.] The 'Kathânakâs' are short narratives and tale. They are known to us chiefly through three modern prose works, which contain obvious marks of having been derived from older metrical collections. They are called—'Vetâlapanchavinsati,' "the 25 tales of the ghost," by Sivadâsa; 'Sukasaptati,' "the 70 tales of the parrot," known in Europe as the 'Tûtinâmeh,' from a Persian translation; and the 'Sinhâsanadvâtrinsati,' "the 32 tales of the statues on the throne of Vikramâditya." The whole series has only been printed in translations into the modern languages of India. Lassen has published part of the Sanskrit original of the 'Vetâlapanchavinsati,' and the commencement of the 'Sukasaptati,' in his 'Anthologia;' and Prof. R. Roth has given extracts from the Sanskrit text of the 'Sinhâsanadvâtrinsati,' in the 'Journal Asiatique' for 1845, vi. 278, ff. But there is another still more important work, a great collection of all the existing tales, which was undertaken by Somadeva of Cashmere, in the 12th century; it is entitled 'Vrihatkathâ,' "the great narration," or 'Kathâsaritsâgara,' "the ocean of the streams of narrations." It is written in the epic metre, and in a simple style. (About a fourth part of the work has been published by Brockhaus, Leipzig, 1840.) Viewed with reference to their matter, the works of this collection are peculiarly interesting to us, since even in the middle ages they had found their way to Europe under various forms, as 'The Book of the Seven Wise Masters,' &c.; and the knowledge of the original text clears up many difficult questions of literary history. Some of the oldest and best of the 'Tales of the Thousand and One Nights' have been drawn from this source, and even in the Arabic version they retain many features which belong only to India. See Prof. Benfey's translation of the 'Panchatantra,' Leipzig, 1859, 2 vols.

There are two other kinds of narrative works, which need only be noticed briefly: the *champûs*, which are narrations in prose and verse, sometimes written in the artificial style; and the *charitras*, which are short and wonderful stories from the history of some celebrated man. Of this last kind there are two which relate to the kings Vikramâditya and Bhoja, and at first sight appear to contain some valuable information; but they are entirely without authority, and have only served to introduce error into questions of literary history. To the elaborate prose works of this class belong the 'Dasakumâracharitra,' or "the adventures of the ten princes;" and the 'Kâdambari;' the former by Dandi, about the middle of the 11th century, the latter by Vânabhatta, of a somewhat later date, and composed in a very abstruse style. Lastly, in the 'Vâsavadattâ,' a romance in prose, written by Subandhu probably as early as the 7th century, the display of alliteration and the love of ambiguity of import are carried to such an extent that the work may truly be called an entire volume of puns.

Before we proceed to the scientific literature, we must add to the narrative class the scanty remains of

Historical Literature.—The peculiarly contemplative cast of mind which distinguishes the natives of India, and the circumstance of the whole country having never been formed into a single kingdom, but consisting of small independent governments, will sufficiently account for the almost entire want of historical writings. With the exception of a very modern chronicle of Orissa (abridged by Stirling, 'Asiat. Resear.,' xiv.), there is only one historical work in existence in the Sanskrit, 'The Chronicle of Cashmere,' properly entitled 'Râjatarangini,' "the stream of the kings;" it was written in the 12th century by Kalhana, partly from ancient sources, which he specially mentions. There have been three successive continuations of this chronicle, which describe the period of the Mohammedan dominion down to Akbar. The work is written in the artificial style, in the epic metre, and has a good deal of the form of a 'Purâna.' The first part of it has been drawn almost entirely from Buddhist sources. It was first made known in Europe by Wilson's analysis ('Asiat. Resear.,' xv.); afterwards edited at Calcutta, 1835, 4to.; and lastly, the first six books, with a French translation of the whole work by Troyer, were published, at Paris in 1840-52, in 3 vols. The Buddhists, on the other hand, have a history, chronologically worthy of credit, which is continued according to the series of their patriarchs. Hitherto the only publication of the original Indian text has been that of the 'Mahâvansa,' in Pali, by Turnour. (Colombo, 1837, vol. i., 4to.) This deficiency of historical literature is in some degree compensated by numerous inscriptions of various ages, which have been found in all parts of India, and most of which have hitherto successfully been deciphered. As many of them contain genealogies and other matters which indicate the time when they were written, they are of inestimable value for historical inquiries, being almost the only documents which we possess. As to any other historical notices, we are entirely indebted to the writings of the Greeks, the Chinese, and the Arabians, which have been very useful, at least for settling dates.

Scientific Literature.—The sciences to which the natives of India have been original contributors, are philosophy, grammar, and astronomy, together with algebra.

Philosophy is of great antiquity in India. The contemplative character of the natives must have early led them to metaphysical speculations, and the collision which must soon have occurred between the results of those speculations and the revealed word of the Vedas, would become a principal cause of the wider extension of philosophy. Hence arose many systems; of those which are held to be orthodox we are specially acquainted only with six; but as these six are related to each other by twos, they can only be regarded as three distinct systems. We are acquainted with them only in their complete form, in which they have a mutual relation to each other, and we are not able to point out their historical development.

The *Sânkhya* system however must be regarded as the first and most ancient, and this system, on certain mythological grounds, has been traced back to Kapila. It is founded on a duality of soul and matter (or nature); the first being the free, pure, uncreated, and uncreating principle; the second, the creating power of nature, blind and purposeless. The one cannot be thought of without the other; they form for themselves the yet undeveloped being, and from them proceeds, by a regular gradation, from the spiritual to the intellectual, and then to the most corporeal, the whole visible world. Every human being indeed possesses the spirit, but in union with the senses; and his task is, by the conquest of the senses through the medium of the intellect, to attain to the final deliverance, "moksha," or blessedness, which is accomplished in the "jnâna," that is, the "gnosis," knowledge. But this system had an appearance of atheism, and therefore underwent a reformation in the *Yoga* system of Patanjali. It is here established, that knowledge is the way to attain to the final deliverance, but knowledge itself can only be obtained through "yoga," absorption into God and mystical union with him, and a perfect abstraction from everything which can disturb the mind or awake the passions. The system further assumes, that the pure spirit is the creator, and thus it connects itself with the notions which belong to religion; it also adopts the metempsychosis, inasmuch as it fixes degrees of the yoga; the spirit comes back to inhabit new bodies till it has attained the highest degree of the yoga. The Vedas are also held in esteem as means of knowledge, but they are not valued more highly than other means, since a man is to perform what is said in the Vedas freely, and not merely on account of the written word. Hence has arisen the saying, that the "yogin" is exalted above the Vedas.

The doctrines of the Buddhists are founded on the Sânkhya system, which they carry out into all its consequences, both in their religion and politics. [BUDDHA.]

The second system is the *Nyâya*, of which Gotama is the author. This system is entirely confined to logic and dialectic, on which it has been constructed even in the most minute particulars. It is therefore more in accordance than the Sânkhya with the other systems; and as the natives of India generally have bestowed much labour on the study of logic, so philosophers also of all the different sects have occupied themselves with it. The number of the Nyâya writings is very great. The *Vaiseshika* system may be looked upon as a reformation of the Nyâya. It is derived from Kanâda. It applies the logical principle to nature, and has arrived at a complete atomic doctrine by the resolution of all substances into their elements. It asserts that there is a union of atoms, which however is purely mechanical; so that, contrary to the Sânkhya, in its consequences it necessarily leads to materialism.

The third system, the *Mîmânsâ*, the first teacher of which was called Jaimini, is directly opposed to the two former. It maintains religion and the revealed word of the Vedas, and is a positive theological system. Accordingly it is occupied chiefly in commenting upon the Vedas, and in reconciling their contradictions. The first part of this system is predominantly practical; it is called 'Pûrvamimânsâ,' "the first Mimânsâ;" here also it is affirmed that the final deliverance must be worked out by knowledge, but it limits the knowledge to that of the duties prescribed in the Vedas. The metaphysical part of this system is displayed in the *Uttaramîmânsâ*, commonly called the *Vedânta*. Here too knowledge is considered as the condition of deliverance, but still the sacred word of the Vedas is the great rule by which all thought is to be regulated. The Vedânta required philosophy and dialectic, and has therefore adopted from the other systems everything **not contradictory** to its objects; the consequence of which is, that one-half of the philosophy is given up, and the Vedânta is intermediate between philosophy and dogmatism, as was the case in the Christian system of the schoolmen. It has been however of great service in the later corrupted times, in regenerating the old religious and political system, and in maintaining it to the present time. The two greatest restorers of this system were Kumârilabhatta in the 6th century A.D., and Sankarâchârya in the 7th and 8th, both of whom contributed largely to the expulsion of the Buddhists. The latter travelled through the whole of India, combating and refuting the opposite sects. The system is indebted to him for its perfection, and it is even now universally received throughout India in the form into which he brought it.

The heterodox systems ate chiefly known to us through the refutations of them by their opponents, especially Sankarâchârya, for the writings themselves have been intentionally destroyed. They are alluded to in Manu, and they are combated in the 'Râmâyana;' which are proofs of their antiquity. The most important among them is that of the *Lokâyatikas*, a connected continuation and development of the *Vaiseshika* doctrine, and a perfect materialism. Those who adopt this system do not announce a final deliverance as the highest aim, but deny a future existence, and regard the soul as a material substance. The only source of knowledge is considered to be that of a true perception by means of the senses; and the world is held to be uncreated and eternal; they consequently deny the first cause of things, and are perfect atheists.

(Colebrooke, 'Essays on the Religion and Philosophy of the Hindus,' London, 1858, pp. 143-269; Ballantyne, 'Christianity contrasted with Hindu Philosophy,' 1859, pp. xv. xxxviii.; Mullens, 'Religious Aspects of Hindu Philosophy,' 1860, pp. 1-174; Lassen, 'Ind. Alt.,' i. 830-36, ii. 509 f. 1165 f., iii. 421-39; Weber, 'Ind. Lit,' pp. 210-20; Dr. Ballantyne commenced in 1849 to edit at Benares the Sûtras (short aphorisms) of the six principal schools of philosophy, in Sanskrit and English; 'Sarvadarsanasangraha' (short notices of the different systems of philosophy), by Mâdhavâchârya, Calc., 1858; 'Sânkhyapravachanabhâshya,' ed. Hall, Calc., 1856; 'Sânkhyakârikâ,' ed. Wilson, Oxford, 1837; '**Bhagavadgitâ,' ed.** Lassen, Bonn, 1846; Calc., 1856 (with the commentaries of Sankara and Sridharaswâmin); transl. by Thomson, Hertford, 1855; M. Muller, 'On the Nyâya' (app. to Thompson's 'Laws of Thought'); 'Bhâshâ Parichheda,' and 'Siddhânta Muktâvali,' ed. Roer, Calc., 1850; 'Vedântasâra,' by Sadânanda, Calc., 1855; 'Bâdarâyana's Brahmasûtras,' ed. Roer, Calc., 1854; 'Sârîraka Mîmânsâ Bhâshya,' by Sankarâchârya, Calc., 1829, 4to; 'Sankara, sive de Theologumenis Vedanticorum, auct. Windischmann,' Bonn, 1838, 8vo.)

Grammar.—The *Philological Sciences* arise among an ancient people as soon as a sacred literature gives occasion to their growth. The Vedas were written in a language which soon became obsolete. The necessity of defending them against corruption and innovation, and of preserving their correct interpretation, naturally **led to grammatical** inquiries; and as the Sanskrit language is in itself **so original**, regular, and perfect, that its laws are easily discovered, philology has become the most valuable part of Indian literature. The Indian grammarians are far above those of any other ancient people; and they have a strong predilection for this science, and have treated of it in numberless writings. The first beginnings of Sanskrit grammar reach back to very remote times, and are included in the collected system of the Vedas. The oldest grammarians appear also as the authors of the 'Upanishads.' Here too we are unable to trace the gradual formation of the science; the system appears at once in its complete state in the 'Sûtras,' or Aphorisms, of Pânini, who certainly did not live later than the middle of the 4th century before Christ. He takes notice of a series of older grammarians, as well as of schools; and though in certain particulars there was some variation in what they taught, yet in general the system was the same, and they had the same technical terms. The form in which grammar is presented is one peculiar to the natives of India, and they apply the same principles to other sciences, as for instance philosophy. Everything is compressed into rules, which are brought into the most concise forms of expression possible, and the grammatical categories are expressed by a kind of figures or algebraical signs. They are intended to be committed to memory, and without a commentary they are unintelligible; they are all connected one with another. (Published at Calcutta, 1810; at Bonn, 1840, by O. Boehtlingk. A severe criticism on this edition is contained in the introduction to 'The Mânava-Kalpa-Sûtras' edited by Dr. Goldstucker, London, 1861. See also Lassen, 'Ind. Alt.' ii. 479 ff.; Weber, 'Ind. Lit.' p. 199 ff.; Weber, 'Ind. Studien,' i. 141, ff.; **Muller, 'Anc.** Sanskrit Lit.', p. 138, 150 ff.; **Westergaard, 'Om de Œldste Tidsrum i** den indiske Historie.' **Copenhagen, 1860, p. 72 ff.**) Pânini is not systematic, but indeed very arbitrary in his arrangement, which appears to have been adopted merely from the necessity which the object of attaining the greatest possible brevity imposed upon him. The whole of more modern Sanskrit grammar is founded on Pânini, and at first grammarians were merely occupied in explaining and correcting him. Two ancient commentaries by Kâtyâyana (who is also called Vararuchi) and by Patanjali, who in later times have themselves been copiously commented upon, are nearly as old as Pânini himself. In comparatively recent times, grammarians began to take some pains to reduce the 'Sûtras' to a system, and to compose grammars more in accordance with European notions. Here the 'Siddhântakaumudî' must be particularly mentioned, which was written by Bhattojidîkshita about the year 1600, and has served as the foundation of a number of more modern works. ('Siddhântakaumudî,' Calcutta, 1812, 4to.; 'Laghukaumudi,' ibid, 1827, and Mirzapore, 1849.) All these are entirely occupied with teaching the grammatical forms, and it is only as opportunity offers that they give a few syntactical rules. Syntax, on the contrary, is developed in many distinct works, and is grounded on the logic of the Nyâya system, which is a proof of enlarged and correct views. So in like manner the different Prakrit dialects have been exhibited in their separate grammars. The oldest work of this kind is the grammar of Vararuchi, which belongs to the 4th century before Christ (the greater part of it published in Lassen's 'Instit. Linguæ Pracr.,' the whole edited by Cowell, Hertford, 1854); it treats of the principal dialect and of the three others which are most nearly connected with it. He is followed by a series of later grammarians, who successively include within the limits of their works more of the inferior dialects. The most important of these grammarians is Hemachandra, a Jain. The canonical books of the Jains being written in the Prakrit, that language is regarded by them with peculiar interest.

Lexicography also had its origin as far back as the Vedas, for the necessity must soon have been felt of collecting and explaining the obsolete words. A work of this kind, entitled 'Nirukta,' (edited with commentaries, by R. Roth, Göttingen, 1852) forms an essential part of the Vedas themselves. For the purpose of perfecting grammar, it was afterwards found necessary to make alphabetical lists of the verbal roots. The nouns, chiefly for the purpose of fixing the genders, were arranged by themselves, not alphabetically, but according to the subjects to which they belonged. The chief work of this class, which has served as a foundation to all the later ones, is the 'Amarakosha' ('Amarasinha'), which they have imitated even in their arrangement. [AMARA, in BIOG. DIV.] Next in celebrity and more complete than the before-mentioned is Hemachandra's 'Abhidhânachintâmani,' from the 12th century (edited by Boehtlingk and Rieu, St. Peterb., 1847). None of these works, of which there are many, completely exhausts the treasures of the language.

Metre.—In like manner, the *Veda-hymns*, which were to be committed to memory, led to the consideration of the laws of metre, and treatises on metre have been ascribed to very early teachers of the Vedas. Here also the more early essays, such as the Nidâna-sûtras of the Sâma-Veda, have been superseded by a work which exhibited the subject as a complete system. Pingala, who is commonly considered to be the same as Patanjali, is said to be the author of it: this work, which, like the whole science, is called Chhandas, has been elucidated by numerous commentaries.

Music.—The theory of music has also been elaborated according to various **systems, but in a strange** manner, for the different notes and **musical scales have been personified.**

Of the musical sciences nothing has been printed except quotations from Bharata's 'Gândharvaveda,' and from the works of Îsvara, Nârada, Pavana and Kalinâtha in the commentaries to the dramas. But several treatises, such as the 'Sangitaratnâkara' by Sârngadeva, the 'Râgavibodha' by Soma, the 'Sangitadarpana' by Dâmodara, the 'Râgamâlâ,' exist at least in manuscript. ('Catal. Codd. MSS. Sanscr. in Bibl. Bodl.', Oxford, 1859, p. 199-201.) See also Colebrooke's copious Treatise on Metre ('Asiat. Res.', x.).

Rhetoric.—To the philological sciences belongs also the Indian system of *Rhetoric*, or rather *Poetry*, in which the rules for poetic composition are deduced, not from any principles of art, but from the existing classical works, with particular reference to the drama, the theory of which is extremely copious, and goes into the nicest distinctions. This theory belongs to a late period. There have been printed the 'Kâvyaprakâsa,' by Mammathabhatta,' of Cashmere (Calcutta, 1829), and 'Sâhityadarpana,' by Kavirâja (Calcutta, 1853), both of which belong either to the 12th or 13th century.

Commentaries.—In later times the Indian grammarians have occupied themselves in writing commentaries, particularly on the works belonging to the Vaidic literature, to classic poetry, and to philosophy and grammar. The most important of the scholiasts with whom we are yet acquainted are Sâyana, Mahîdhara, Sankara, on the first mentioned, Mallinâtha, on the more modern epic poems, and a host of others. The commentators have done good service in fixing and maintaining a pure text, especially in the Vedas and the great epic poems. A philological school was established in Bengal, upon a directly opposite principle, for they began to make editions of classical works, in which most uncritically, according to European notions, they kept to the meaning, but took the liberty of entirely altering the expression. As we have before mentioned, they made such a recension of the

'Râmâyana,' as well as of the 'Sakuntala,' and other dramas. Vopadeva, a grammarian of this school, in a similar manner invented a new grammatical system, according to which he altered the technical expressions of Pânini, without in other respects varying in the smallest degree from this method. ('Mugdhabodha,' Calcutta, 1826, St. Petersburg, 1847.)

Astronomy.—The oldest Indian astronomical documents are the calendars which are annexed to the Vedas, and which, according to Colebrooke, belong to the 13th century B.C., but are at least in their present form, of much more recent date. They include a solar year of 365 days, and are so composed as to determine it correctly. Here also we are unable to point out how the mathematical and astronomical sciences were gradually developed from such simple elements, as we possess them only in their perfected form. Assisted by the system of notation which they discovered, the natives of India have been particularly happy in their methods of treating arithmetic and algebra, which have had such influence on their mathematical studies that they prefer solving geometrical questions analytically, just as the Greeks, on the contrary, solved arithmetical questions by geometry. ('Lilâvati,' by Bhâskara, Calcutta, 1828; Colebrooke, 'Algebra of the Hindoos,' Calcutta, 1817, 4to.).

In the earliest works on Indian astronomy now extant, several different systems are apparent, and these systems have been treated of in five works, entitled 'Siddhântas,' which apparently contain the same theories which were afterwards successively extended and improved. Varâhamihira, at the beginning of the 6th century A.D., compared them with each other, and other astronomers worked them up again under different titles, each with the view of introducing into them his own theory. The most important of all astronomers that preceded Varâhamihira is Âryabhatta, who was the first to free himself completely from all mythological notions; he was acquainted with the motion of the earth about its axis, and estimated more accurately than Ptolemy the precession of the equinoxes. His work, 'Âryâshtasata,' an exhibition of his system in 800 strophes, has not yet been recovered, but his abridgment of it, 'Dasagitaka,' and another work, 'Aryabhattiya,' which in 4 chapters and 123 strophes contains his system of mathematics, are still extant. According to Colebrooke's reckoning, the latest period at which he can be fixed is 478 A.D., and he may have lived two or three centuries earlier; and Whish ('Trans. Asiat. Soc.', iii. 2, 509), fixes the year of his birth about 502 A.D. By the researches of Weber ('Ind. Stud.', ii. 236 ff.; 'Ind. Lit.' p. 221 ff.) and Lassen ('Ind. Alt.', ii. 1114-46) the question whether the Indian astronomy was entirely native, or whether it was constructed with the aid of that of the Greeks, has been finally settled in favour of Greek influence. Âryabhatta, who most probably flourished as early as the beginning of the 4th century A.D., availed himself largely of the progress which the Greeks (especially Hipparchus) had made in astronomy; and he not only improved upon their new theories and inventions, but added also the results of his own independent investigations. In algebra he made even greater progress than the Greeks. Astronomy has not been improved in India since his time; on the contrary, those who have come after him have not relinquished the false views consecrated by religion, but have endeavoured to defend them against him. This was chiefly done by Brahmagupta, the author of the 'Brahmasiddhânta,' in the 6th century A.D., who is the classical astronomer of the moderns, and whose track was followed by Bhâskara in the 12th century, in his work 'Siddhântasiromani.' Since one of the other Siddhântas, the Sûryasiddhânta, has lately been edited in Calcutta (1859), and an excellent translation of the same has appeared in the sixth volume of 'The Journal of the American Oriental Society,' (1860) p. 141-498, we have the means to make ourselves acquainted with all the peculiar features of Hindu astronomy. (See several discussions by Colebrooke in the second volume of his 'Essays,' and an article by F. E. Hall, on the 'Ârya-Siddhânta' in the 'Journ. Am. Or. Soc.', l. l. p. 556-64.

Medicine.—There are many Indian works on medicine, and the systems are various. Many parts of the medical science of India are valuable even to us, as for instance the Materia Medica, in which they were much favoured by nature. The Indian physicians were highly esteemed by the Greeks. In surgery especially they have made considerable progress, and have even discovered and performed difficult operations, as for instance the restoring of noses. The most celebrated medical work, 'Susruta,' has been printed (Calcutta, 1835, 2 vols. 8vo); and Ainsley ('Materia Indica,' London, 1826 and 1831), and more recently Royle, ('On the Antiquity of Hindu Medicine,' London, 1837), and Wise ('Commentary on the Hindu System of Medicine,' Calc. 1845), have done much to make known the Indian systems of medicine.

Natural History.—The observation of external nature still remains in a very low state among the natives of India, and they seem never to have made any progress even towards the commencement of a scientific system of natural history; at least no works of this kind are known.

Study of Sanskrit.—The Sanskrit language was for many years considered unattainable, but towards the close of the last century this study received a powerful impulse, partly from the necessities of the English government in India, and partly from a desire of knowledge among the learned of Europe. The study of the language having been once commenced, its progress was extremely rapid, the acquisition of it being much facilitated by the previous labours of native grammarians; and by the printing of a great number of their most important works, a large part of the literature became generally accessible, an advantage which most of the other oriental languages have not enjoyed. In India this progress has been connected with the names of Wilkins. Jones, Colebrooke, Wilson, Mill, Prinsep, Roer, Hall, R. Mittra, Râdhâkânt Deb. But Europe has not remained behind; and the rich collections of manuscripts in the possession of the East India Company in London, of the Bodleian at Oxford, of the Royal Library at Berlin, and of the Imperial Library of Paris, have been abundant sources, and perhaps more than sufficient to compensate for the peculiar advantages enjoyed by India. In England, the study of Sanskrit was in the first place most indebted to Haughton and Rosen [ROSEN, in BIOG. DIV.]; it now counts among its Sanskrit scholars such men as M. Muller, Goldstucker, Ballantyne, M. Williams, and Aufrecht. In France, it was chiefly introduced through Hamilton in 1804, and cultivated by Chézy and Burnouf. In Germany however Sanskrit has experienced the most cordial reception, though at first, owing to the want of manuscripts, the study of it was prosecuted under the greatest disadvantages. In that country, the knowledge of Sanskrit was chiefly diffused by A. W. von Schlegel and Bopp, both of whom learnt it about the same time in Paris. At present there is hardly a university or college that has not its chair for Sanskrit; and of the success with which it has been studied, the works of Lassen, Roth, Weber, Stenzler, Brockhaus, Benfey, Kuhn, and Spiegel, give abundant proof. Also in other continental countries Sanskrit scholars of eminence, such as Westergaard in Denmark, Boehtlingk and Schiefner in Russia, Regnier in France, Nève in Belgium, and Gorresio in Italy. have done much to promote and popularise the study of ancient Indian literature.

For the *practical study* of Sanskrit we would recommend the following books:—

a, Dictionaries: Wilson's, 2nd ed., Calc. 1832; 3rd ed. by Goldstücker (in the course of publication)); 'Sanskrit-Wörterbuch,' by O. Boehtlingk and R. Roth, St. Petersburg, 1855 ff. (in the course of publication); 'Engl. and Sanscr. Dict.', by M. Williams, Lond. 1851.

b, Grammars: Wilson, 2nd ed., London, 1847; Williams, 2nd ed., London, 1857; Bopp, 'Grammatica critica linguæ Sanscritæ,' Berlin, 1829-32, and his 'Kritische Grammatik der Sanskrita-Sprache,' Berlin, 1845; Boller, 'Ausführliche Sanskrit-Grammatik,' Wien, 1847; Benfey, 'Vollständige Gramm. der Sanskrit-sprache,' Leipzig, 1852, and his 'Kurze Sanskrit-Grammatik,' Leipzig, 1855; Desgranges, 'Grammaire Sanscrite-Française,' 2 vols., Paris, 1845; Oppert, 'Gramm. Sanscrite,' Paris, 1859; Rodet, 'Gramm. abrégée de la langue Sanscrite,' Paris, 1860; Flechia, 'Grammatica Sanscrita,' Torino, 1856.

c, Readers: Johnson, 'Selections from the Mahâbhârata,' London, 1842; 'Sanskrit-Chrestomathie,' by O. Böhtlingk, St. Petersburg, 1845; 'Anthologia Sanscrita,' ed. Lassen, Bonn, 1838; 'Chrestomathie aus Sanskritwerken,' by Th. Benfey, Leipzig, 1853.

d, Works on comparative Grammar: Bopp, 'Vergleichende Grammatik des Sanskrit, etc.', 2nd edit., Berlin, 1856-61, 3 vols.; translated into English, London, 1854, ff., 3 vols.; Bopp, 'Glossarium Sanscr.,' Berlin, 1847; Kuhn, 'Zeitschrift für vergleichende Sprachforschung,' Berlin, 1852 ff., 10 vols.; Kuhn and Schleicher, 'Beiträge zur vergl. Sprachforschung,' Berlin, 1858-61, 3 vols.; many articles in the 'Transactions of the Philological Society.'

SANTALIC ACID. [SANTALIN.]

SANTALIN ($C_{30}H_{14}O_{10}$?). *Santalic acid.* The colouring matter of the *Pterocarpus santalinus*, or red sandal-wood. It was examined by Pelletier in 1814, and is readily obtained by digesting the rasped wood in alcohol, and then diluting the clear solution with water, by which the solution is precipitated of a beautiful red colour; it is tasteless, nearly insoluble in water, but readily dissolved by alcohol, ether, alkaline solutions, and slightly by the oils of lavender and rosemary.

The alcoholic solution of santalin gives different coloured precipitates with metallic solutions: thus with tin it gives a beautiful purple, with lead a violet, iron a deep brown, silver a reddish-brown.

Santalin reddens litmus-paper, and forms ill-defined salts with some bases.

Santalin, or rather the red sanders which contains it, is little used in this country as a dye stuff, but in India it is employed both in dyeing silk and cotton. It is used in pharmacy to give a colour to certain tinctures, but the colour is not generally regarded as a permanent one.

SANTONIC ACID ($C_{30}H_{18}O_{6}$?) *Santonin.* A vegetable principle possessing acid properties obtained from the seeds of the *Artemisia santonica*, or southernwood. Its properties are, that it is colourless, crystallises in six-sided prisms and some other forms, is destitute of smell, and when long chewed is slightly bitter. It is soluble in 4000 to 5000 times its weight of cold water, and 250 times when boiling. It is soluble in alcohol, and in the fixed and volatile oils. When strongly heated, it is decomposed. The alcoholic solution reddens litmus-paper, and with some bases it forms neutral and crystallisable salts; this is the case with santonate of soda and santonate of lime; some of the metallic santonates are soluble and others insoluble in water. None of them is applied to any use.

SANTONIN. [SANTONIC ACID.]

SAP is a mode of executing the trenches at the siege of a fortress, when the besiegers arrive within such a distance from the covered-way that the fire from thence becomes too dangerous to allow the men to work on the ground without being protected by some covering objects, as gabions, placed between themselves and the enemy.

The process of sapping varies with the distance from the works of the fortress and the degree of activity with which the fire of the defenders is kept up. It is, therefore, divided into what is called the *flying sap* and the *complete* or *full sap*. In ordinary circumstances, in sieges, before the introduction of rifled ordnance or rifles to any great extent, the flying sap began to be used in forming the second parallel trench, which may be about 320 yards from the covered-way; and it is executed in the following manner.

If the distance from the depôt of siege-materials to the place of the intended trench is not too great, every man carries two gabions, one on each side of him, or both slung at his back; he carries also a pickaxe and a spade, and in the first case these are fixed in the gabions, but in the latter he carries them in his hands. If the distance which the working party has to march is considerable, this burden would be too fatiguing, and then each man carries on his shoulder one gabion together with a pickaxe or a spade. Carrying the gabions one on each side has the advantage of permitting the man to carry his musket slung. The work is begun at night, and when the sappers have arrived at the ground where the tracing-line for the intended trench has been laid down, they set up their gabions a few inches in front of that tracing-line, the officers observing that the row of gabions in its whole length is correctly placed. The portion of trench to be executed by each sapper, or workman, is equal in length to the space covered by two gabions (about 4 feet): the men sit down or otherwise keep themselves covered till the order is given to commence digging, and when the number of men who constitute the working party is greater than suffices to allow one man to every two gabions, those who have not room to work retire to a little distance till they are required to relieve the others. A man may fill his two gabions with earth in about a quarter of an hour, and then they will be proof against a musket bullet, except at the place where they touch each other; after this the earth obtained in executing the trench is thrown beyond the gabions towards the fortress. During the progress of the work the gabions are pushed a little way outwards at the top, in order that they may effectually resist the pressure of the earth which they are to retain; and they are sometimes crowned by two or three rows of fascines which are laid upon them in a direction parallel to the trench.

If the work proceeds by day and night, the parties are relieved every eight hours; and a trench executed by flying sap may, in soil of medium tenacity, be completed by three reliefs of men.

When the approaches of the besiegers have advanced so near the covered-way that the fire of the defenders will no longer permit the men to bring the gabions openly to the ground, the full sap is practised. For this purpose the sappers are divided into brigades of eight men each; and of these a demi-brigade only of four men is employed in the formation of a single line of trench. The party is provided with a mantelet (a plate of iron thick enough to be musket-proof, and capable of being moved forward by being mounted on small wheels) by which the men may be covered in front; or, instead of this machine, there is provided for the same purpose a great gabion called a sap-roller. This is a cylinder of basket-work, 6 feet long, and about 4 feet diameter, and having within it a gabion of equal length, but about 2 feet six inches diameter; the axes of the two gabions are coincident, and the space between the exterior of the one and the interior of the other is stuffed with fascines, by which means it is rendered musket-proof. The sap-roller turning on its convex surface is found to be more manageable than the mantelet; and when it is intended to form a trench in any proposed direction, by breaking out from one which has been already executed, it is raised over the parapet of the latter trench, and gradually lowered on the exterior side, being guided by means of a hook, so that it may have a position perpendicular to the line of the intended trench. The leading sapper of the demi-brigade then cuts through the parapet, and pushing the sap-roller forward about 2 feet, he hastily places an empty gabion in rear of that extremity of the sap-roller which is nearest to the enemy's work, in order that he may be covered on his flank: then kneeling behind the gabion, he excavates a portion of a trench, 18 inches wide, and as many in depth, leaving a berme about 12 inches broad between the gabion and the nearest edge of the excavation, and throwing the earth into the gabion. When this portion is dug, the sap-roller is advanced about 2 feet farther, and another gabion is set up in its rear, adjacent to the former, and in the line of the intended trench; a short fascine or two sand-bags (bags full of earth), are placed one above another in the hollow between the two gabions, in order that a musket-ball may not be able to penetrate through the screen in that part. The sapper then excavates as before, and having filled the second gabion, a third is handed to him, which he places and fills as he continues to advance. The second sapper of the squad follows the first, keeping a little way in his rear, and increases the width only of the trench by 20 inches on the side which is farthest from the line of gabions, and he also throws the earth into and beyond the gabions. The third sapper follows, and increases the depth only by 18 inches on a breadth of 20 inches measured from the rear side of the trench towards the gabions; and the fourth sapper excavates a portion 3 feet deep, increasing the breadth of the trench towards the rear by 10 inches. By this arrangement the tasks of the different men are rendered nearly equal, and complete cover is obtained when the work of the third man is executed. The four men thus form a trench 4 feet wide and 3 feet deep, and a step is left on the side nearest to the gabions for convenience in standing to fire over the parapet. The working parties from the infantry of the line afterwards complete the trench by increasing the width to its usual extent, about 12 feet.

Since the head sapper has the most dangerous post, the second, third, and fourth sappers relieve him by alternately taking his place; and the work advances about 8 or 10 feet per hour, according to the tenacity of the earth.

If the fire of the place should be considerably subdued by the action of the besiegers' batteries, the full and flying sap may be combined in order to expedite the approaches. Thus a party of sappers advancing on their hands and knees, and rolling gabions before them, on arriving at convenient places set up the latter in line; then two or three men, at certain intervals from each other, dig pits behind the gabions, in order to get cover, and afterwards work towards each other, making a small trench, and filling the gabions with earth. The trench may subsequently be made of the required width.

When the distance to be passed over to the work attached becomes very small, the angle formed by the adjacent zig-zags becomes very small, or rather when 100 yards of the zig-zag does not carry the approaches so much as 32 yards in advance (those being the proportionate rates at which the single and double sap can be executed), then the line of trench is carried on directly towards the place, sometimes by a simple trench with traverses at intervals, and sometimes by what is called the double sap. This is performed by two squads or demi-brigades, who work parallel to each other, each being covered in front by its own sap-roller, and there is a third roller in rear of the small interval between the others. A row of gabions is placed on the right of the trench executed by one squad, and on the left of that which is executed by the other; the distances between the rows of gabions is about twelve feet, and traverses are formed in the trench at intervals as the work advances. These project alternately from opposite sides, so as to leave a serpentine passage along the trench. Hence this is termed the *serpentine* sap. There is however another form of double sap, called Jebb's, or the double direct sap, which is now adopted in the English service. This is formed by three brigades of sappers with four sap rollers in front. The three brigades work parallel to one another, and drive three saps straight forward. Traverses are formed as the sap proceeds, projecting alternately from each side like teeth and overlapping one another. The intermediate space is then excavated, and a covered passage is thus obtained. The distance between the parapets on each side is 22 feet, or the breadth of eleven gabions.

SAP-GREEN, a pigment, prepared by evaporating the juice of the berries of the *Rhamnus catharticus*, or buckthorn, to dryness, mixed with lime. It is soluble in water, less so in alcohol, and insoluble in ether and oils. Acids redden it; but the alkalies and alkaline earths restore the green colour. [COLOURING MATTERS.]

SAPOGENIN. [ESCULIC ACID.]

SAPONIC ACID. [ESCULIC ACID.]

SAPONIFICATION. [FATTY ACIDS.]

SAPONIN. ($C_{24}H_{20}O_{14}$?) A colourless non-crystalline body, found in the soapwort (*Saponaria officinalis*) and many other plants. The *senegin* of Gehlen appears also to be identical with this substance. Saponin is extracted from the root of the soapwort by boiling alcohol from which it is deposited on cooling. It is inodorous, tastes at first sweet, then astringent, and finally acrid. It is soluble in water in all proportions, forming a remarkably saponaceous solution. It is almost insoluble in ether and in absolute alcohol, but readily dissolves in dilute alcohol. Lime-water does not precipitate aqueous solutions of saponin. Introduced into the nostrils a very minute quantity of powdered saponin occasions violent sneezing. [ESCULIC ACID.]

SAPPAN WOOD. [BRAZIL WOOD.]

SAPPERS AND MINERS, ROYAL, formerly the name given to the non-commissioned officers and privates of the corps of Royal Engineers. The men and officers are now collectively termed the Royal Engineers, but in specifying any individual private he is termed sapper — of the — company of Royal Engineers. They are employed in building and repairing permanent fortifications, in raising field-redoubts and batteries, in making gabions and fascines, in digging trenches [SAP], and executing galleries of mines during sieges, and also in forming bridges of rafts, boats, and pontoons.

The troops belonging to the department of the engineers were first embodied at the termination of the war between Great Britain and her American colonies, and they then received the designation of Royal Military Artificers. The duke of Richmond, who was at that time master-general of the ordnance, formed them into independent companies, and caused them to be stationed chiefly at Portsmouth, Plymouth, Chatham, Dover, and Gibraltar. In the year 1807 the Military Artificers constituted a corps of 32 companies, each consisting of 126 men; and a sub-lieutenant was attached to each company, which was placed under any senior captain of engineers who might happen to be where the company was stationed. But the want of a proper organisation, and of officers permanently attached to the troops, gradually brought on a relaxation of discipline and a neglect of the particular duties for which the men were intended; it is even said that when detachments were to be drawn from the companies for any intended expedition, the engineer officers who selected the men sent only those who were the least efficient, and that consequently, during the first years of the war against the French in Spain, the service suffered much from the inexperience of the troops of this class.

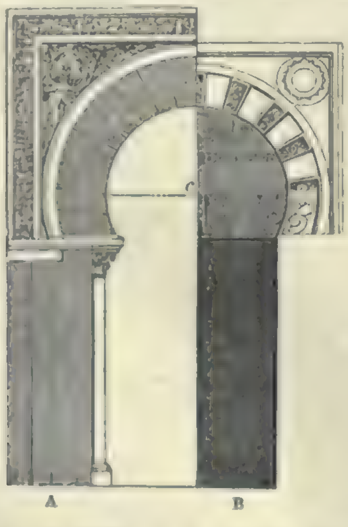
After the failure of the attack on Badajoz, in 1811, it was proposed to select some companies from the corps of Royal Military Artificers, and to form them into a body expressly for the purpose of executing field-works; and in the following year this proposal was carried into effect. Lieutenant-General Mann, who was made inspector-general of fortifications, obtained permission to have the name of the whole corps changed into that of Royal Sappers and Miners; and lord Mulgrave then formed at Chatham the institution at which the men have ever since been regularly instructed in all the duties connected with military engineering. The junior officers of engineers were at the same time appointed to act as the regimental officers of the companies. This institution has been from the first (April, 1812) under the direction of Colonel, now General, Sir Charles Pasley, K.C.B., an eminent officer, who as an engineer had previously distinguished himself in the service of his country.

A detachment, consisting of 300 men, was sent, in 1813, to perform the duty of sappers and miners at the siege of St. Sebastian, where they rendered essential service. In 1814 a brigade of engineers was attached to every division of the army; each brigade consisted of a company of sappers and miners, with horses and carriages sufficient to convey the tools necessary for the work of 500 men; and five companies of sappers and miners served with the pontoon train, which consisted of 80 pontoons, with the forges, waggons, &c. The whole corps was under the orders of a brigade-major of engineers.

From 1812 to the peace in 1814, the corps of sappers and miners amounted to 2861 men; and during the hostilities in 1815, it consisted of 2421 men. At present it consists of 36 companies, and 4337 men, exclusive of officers; and, besides the regular course of instruction in sapping, mining, making gabions, fascines, &c., the men are taught the most elementary principles of fortification, the manner of drawing plans and sections of buildings, and, to a certain extent, the art of land-surveying. Several of the companies are employed in the colonies in the exercise of their professional duties; and of those which remain in this country, some are engaged under the officers of engineers in the mechanical operations connected with the ordnance survey of Great Britain and Ireland which is being carried on by the war department; parties of the corps also regularly attend the Royal Academy at Woolwich and the Military College at Sandhurst, where they assist to execute, for the instruction of the gentlemen-cadets, the several works connected with the practice of field-fortification. It ought to be mentioned that the troops of the corps have invariably, in whatever part of the world they have been employed, conducted themselves as intelligent men and steady soldiers.

SARACENIC ARCHITECTURE, is the term usually applied in this country to what would perhaps be better named Mohammedan architecture, since it embraces the architecture of all Mohammedan peoples, or Arabian architecture, from the race with whom it originated. But though the style may be traced back to them, the Arabians cannot be considered as themselves the inventors of it. They had in fact no distinctive style of their own, when the rapid spread of the religion of Mohammed and the conquests of his followers rendered necessary the erection of numerous religious edifices, and called into existence a new style of architecture. Mohammed is said to have built a mosque at Medina, but it was a structure of the simplest kind, and he left no directions in the Koran for the guidance of his disciples in erecting others. Hence, as has been often pointed out and is now generally admitted, the Mohammedans wherever they secured a standing adopted the architecture of the subjugated race. Thus in Persia we may clearly trace in Mohammedan buildings the older Persian type; in India (as was observed under INDIA, ARCHITECTURE of) that of the Hindus; in Spain the debased Roman or early Romanesque; in Egypt, Syria, and Turkey, the Byzantine; but everywhere this native character was modified and adapted, overlaid with a certain exuberant oriental fancifulness, imbued with Mohammedan feeling: in short combined with a new and foreign element, instead of being prosaically copied as it stood; and thus was rapidly evolved a distinct and well-characterised style.

Fig. 1.



What may be regarded as the typical varieties of the earlier Saracenic architecture are those which appeared in Spain in the 8th century of the Christian era, and in Egypt somewhat earlier: its later form appeared in Constantinople. In each of these a striking and distinctive feature is the horse-shoe arch. But this though a peculiar is by no means a constant feature of the style, or used to the exclusion of other forms of arches. On the contrary there are several varieties, and among them is the pointed arch, which is already a well-established form in the mosque of Ahmed Ibn Tooloon, erected at Cairo in the 9th century, and is of frequent occurrence in other Mohammedan structures erected in that city in the 10th century. The arch being so essential a characteristic of the style we give a few of its various forms in the annexed figures.

Fig. 1 is an example of the horse-shoe form, having the centre *c* on the diameter of the arch raised above the chord or spring of the curve (the dotted line), and consequently the curve itself is greater than a semicircle. The same figure further exemplifies some differences of application, the side or half A showing the arch supported on columns, the other without columns; besides which it illustrates other variations; for on the side B the head of the arch is closed over a square-headed aperture not wider than the span or chord; whereas on the side A the opening between the columns is as wide as the diameter of the arch itself in its greatest width through the centre *c*.

Fig. 2 is an instance of a pointed horse-shoe arch, it being struck from two centres, which, as in the other case, are elevated above the line of the impost, or spring, from which the curve commences. This figure also exhibits two varieties of decorations, both of them by scalloping; one half being scalloped on the intrados, or edge of the

Fig. 2.

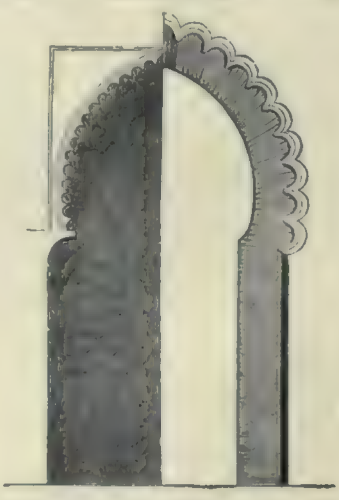
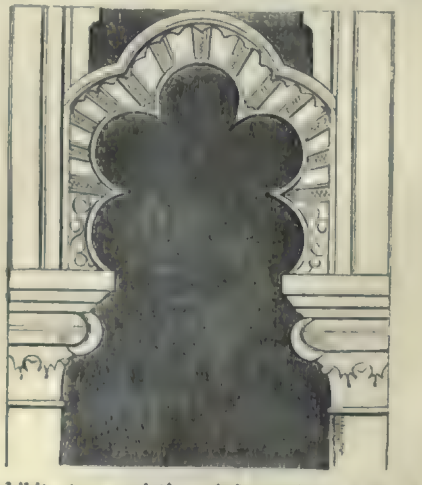


Fig. 3.

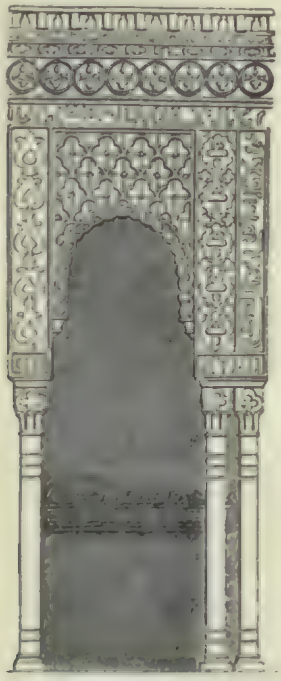


arch itself; and in the other, the extrados, or outer circumference, being so cut, or more properly speaking, the edge of the face of the wall within which the arch recedes: of which kind is the gate in what is called the Casa del Carbon at Granada.

The next example is of what may be called the cusped or scalloped arch, strictly so termed, the outline being produced by intersecting semicircles, similar to the trefoil-headed compartments in our Gothic windows; but beyond that general resemblance, which certainly goes some way to confirm the opinion that the Gothic style borrowed something from the Saracenic, the character is altogether different, not only because it is here the whole arch which is so shaped, instead of merely a subdivision within a larger opening, but also both on account of the external moulding following the same form, and of quite a different mode of decoration. In Gothic architecture the spandrels, or triangular spaces between the foils, are panelled with splayed surfaces uniting in the centre. Arches of the kind here shown occur in the sanctuary of the great mosque at Cordova (8th century), where they rest upon columns which both in their capitals and shafts bear considerable similarity to Corinthian ones, except that they are shorter and without bases, and are therefore very different from the slender pillars peculiar to Arabian architecture.

Fig. 4 exhibits an example of such pillars, and also another variety of Saracenic arches (from the Court of the Lions in the Alhambra, 13th century) very unlike any of the preceding specimens, it being circular-headed, and *stilted*, that is, it is considerably more than a semicircle, its height in fact almost equal to its breadth, but, instead of contracting downwards, like the horse-shoe form, it is continued down straight to the impost, whereby the arch or semicircle has the appearance of being raised or *stilted*, and made loftier than the arch itself would else be. It also exhibits another peculiarity which the Arabs seem greatly to have affected, namely, *corbelling*, or resting arches upon brackets which serve as their imposts; owing to which such arches have the appearance of being suspended over the opening below, which becomes wider and the support or pillar slenderer in proportion to the projection given to the corbels.

Fig. 4.



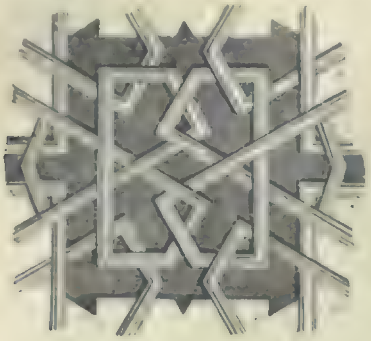
The above will suffice to show the principal varieties, in which we have chiefly attended to the form of the arches themselves, without attempting to show detail and decoration, to which it would be impossible to do any sort of justice upon so contracted a scale, although it may serve for mere explanation. As supplementary however to what has been said, it should be observed as one characteristic of the style, that whatever their shape, or however applied, arches are generally placed within a square-headed panel or compartment, variously ornamented, and frequently surrounded with a margin or border similar to the square label in Gothic architecture. Sometimes there are two margins or labels, and the space between them is filled up either with inscriptions or other decoration. This mode however was confined to large arches, not supported upon columns, but forming an opening through a wall, for a gate or door; and it was for such purposes that the horse-shoe arch was chiefly used, particularly for entrances to mosques. These were further distinguished by the breadth and richness of the archivolt or border surrounding the arch; and which was sometimes equal to the radius or semidiameter of the curve. In some instances the whole archivolt was uniformly decorated; in others only at intervals, or on the alternate voussoirs or arch-stones, some idea of which may be obtained from B, *fig.* 1.

Pillars are commonly of exceedingly slender proportions, almost to apparent insecurity; but owing to the style of the embellishment this lightness of particular forms tends to heighten the general luxuriance. Some have imagined that this element of slenderness in regard to pillars indicates a tent origin of the style; and that while the pillars themselves were fashioned in imitation of the poles which supported the awning, the idea of the latter was in a measure kept up by the general decoration of various devices in mosaic work, and painted stucco, or glazed tiles, which gave to the whole the semblance of being covered with richly-patterned carpeting or embroidered tapestry; not indeed in exact imitation or so as to aim at illusion, but with just that degree of adherence to a prototype which is observable in all artist-like architectural decoration. This tent-like character it has been suggested was further kept up by concave ceilings and cupolas, emblazoned with painting and gilding. The whole surface, in fact, was frequently broidered over with decoration, which consisted almost entirely of ornamental patterns composed either of foliage or geometrical figures, though occasionally with an intermixture of both. The decorations of the former class have given rise to the modern term *Arabesques*, as indicating scroll-work and foliage ornament filling up a frieze or compartment, although it is not very correctly applied, being usually intended to express a combination of animal and vegetable forms, human figures, and those of birds and quadrupeds terminating in foliage and flowers; whereas no such mixture occurs in Arabian architecture, all imitation of the human or even animal shape being interdicted by the Mohammedan law. Their geometrical patterns exhibit singular beauty and complexity, inexhaustible variety of combinations, and a wonderful degree of harmonious intricacy, arising out of very simple elements; to which must be added the variety produced by colour also, whereby the same arrangements of lines and figures could be greatly diversified. Hence though apparently quite unmeaning, and intended only to gratify the eye, such embellishment must have powerfully recommended itself to a people both imaginative and contemplative, and whose fancy would find occupation in patiently tracing and unravelling the manifold intricacies and involvements, the mazes of what at first sight looks like a mere labyrinth, until its scheme unfolds itself; but merely momentarily as it were, being again lost when attention is diverted from it to particular parts. It is on this account that Hessemer, Jones, and others who have paid special attention to the subject, assign so very high a value to Arabian decoration, as being strictly ornamental and strikingly characteristic.

One very prevalent and very peculiar element of Arabian decoration is the use of inscriptions evidently with reference to their ornamental effect. So far there is a very striking analogy between the practice of the Moslems and that of the ancient Egyptians; if the latter covered the walls of their edifices with hieroglyphics, the others inscribed theirs no less profusely with sentences; and the characters of their ordinary writing, elegant and fanciful in themselves, were as studiously ornate and calligraphic as possible; and so well do they harmonise with the rest, as to seem to belong to the embellishment, and to have sufficient value as such independent of their meaning. Neither was the effect of colouring and gilding wanting to set off the inscriptions in the most brilliant manner. The colours chiefly used were the primaries, red, yellow, and blue; the secondaries, except in the decline of the style, being only used in the lower and subordinate parts of buildings. The use of these colours appears to have been most profuse; gilding was also freely employed. In short, even by those who consider much of it to have been in false taste, architectural decoration must be allowed to have been carried by the Arabians to a very high pitch; and although it may be too florid, too prodigal, too *inflated*, and overlaid with ornament, it well deserves to be studied, as many ideas may be derived from it, for novel combinations both of forms and colours. And for such study ample materials are supplied by Mr. Owen Jones's splendid work on the 'Alhambra,' and Hessemer's 'Arabische Bauerzierungen;' in both of which publications the plates exhibit the original colours. The general reader will hardly need to be reminded that Mr. Jones's admirably executed Alhambra Court at the Crystal Palace affords a means of examining copies the actual size, made from casts taken by Mr. Jones at the Alhambra, of the finest and most elaborate examples of Moorish ornamental work at its most advanced stage; but we may point out that the little 'Handbook of the Alhambra Court,' written by Mr. O. Jones, contains much valuable information on the principles of Saracenic ornamentation, and indeed on the second period of Saracenic architecture generally.

Lattice or open trellis-work was another fertile source of embellishment, and was very much akin to the perforated tracery frequently met with in Gothic buildings. In this respect the two styles display great similarity of taste, distinguishing themselves herein from almost every other, notwithstanding that each has a peculiar character of its own. But in Saracenic architecture the interstices are smaller, and the design fills the whole of one aperture; whereas in the Gothic style the ornamental tracery is confined to the heads of windows. Besides which, the character of Saracenic tracery is altogether different, it being composed of straight lines, frequently so disposed as to form stars in some parts of the design. As far as an idea of the peculiarities of the style in this respect can be formed from a single specimen, the example here annexed (from Hessemer) of a portion of a window in the mosque of Hakim at Cairo, may be of some assistance. The pattern is rich and playful; and notwithstanding that, although regular, it appears at first sight to be rather complicated, will be found to be composed of merely a repetition of the same forms, yet producing a constant variety, according as the lozenge or the star is fixed upon by the eye as the centre from which the rest of the pattern diverges.

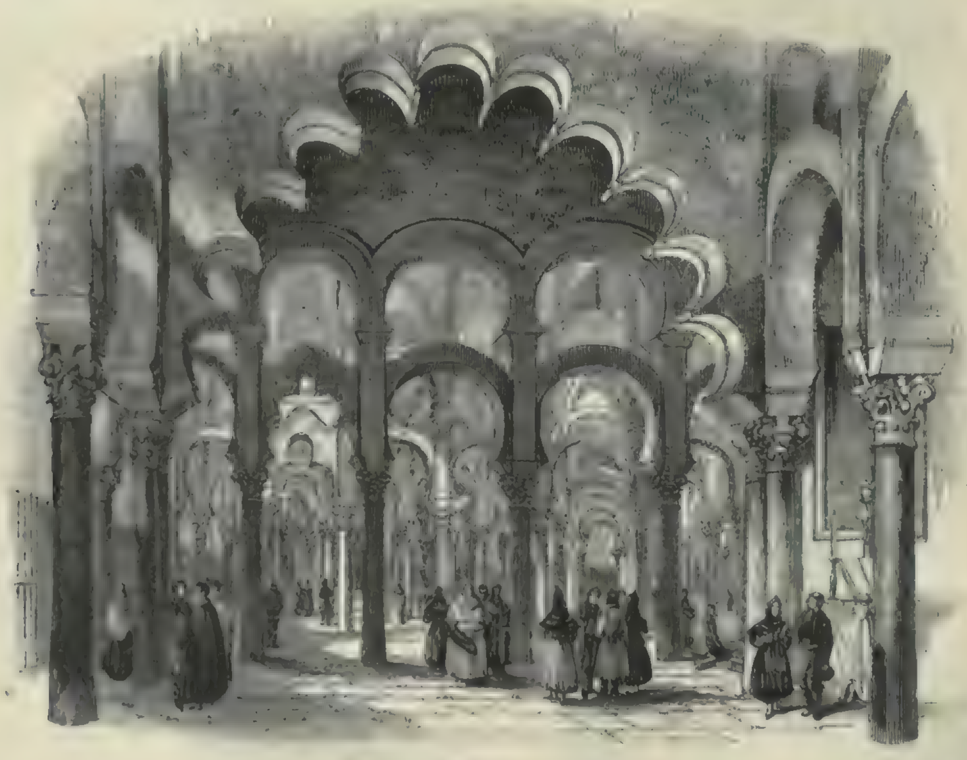
Fig. 5.



Of perforated battlements and parapets, this style furnishes some exceedingly rich and tasteful specimens. Several of them are exceedingly intricate and delicate also, and may therefore, almost without exaggeration, be compared to lace-work as seen against the sky. Of this kind are the parapets of the mosques Lashar and Akmer at Cairo, which in some parts have perforated battlements of fanciful outline rising above the general parapet of open-work. Curves, forming pointed horse-shoe arches, occur in some of the patterns; further than this it is impossible to pretend to describe them, except it be to remark that the stone-work is very slender, and the open spaces large in proportion, and that the ribs or stems of which the former is composed have something the resemblance of being interwoven, one passing alternately before and behind the next, after the fashion of wickerwork.

Equal fancy and diversity of invention are shown in the devices of mosaics and pavements, many of which appear exceedingly elaborate, although, when analysed, they are found to be very simple in principle: for instance, some patterns exhibiting octagons, stars, and other figures, are produced merely by series of zigzag lines intersecting each other at right angles, different combinations being obtained according as the points of the zigzag are turned from or towards each other. Among the other ornaments which mark this style, the honeycomb fretwork and stalactite-like drops, or pendents of ceilings and roofs, deserve to be mentioned: of these, the rich example in the Alhambra Court, a copy in full size of the stalactite roof of the Hall of the Abencerrages, but coloured and gilt in accordance with what Mr. Jones conceives to have been the appearance of the hall in its original state, will at once recur to the memory. Another characteristic form of ornament is that of the small star-shaped apertures cut in a sloping direction through the domes or vaults over baths, &c., for the purpose of admitting only a subdued degree of light.

The above are characteristic elements of the style generally. But there are others equally characteristic of the Asiatic varieties, though not found in the Spanish. Of these, a constructive feature, as striking as the arch itself, is that of the *dome*. For the most part domes occur in mosques and other religious edifices, but they are also usual in tombs. Domes were derived directly from Byzantine examples, and were therefore pendentive in character; but following the Oriental tendency to inflation and luxuriance, they were variously altered in size, application, and ornamentation, and ultimately in Persia, Turkey, and still more extravagantly in India [INDIA, ARCHITECTURE OF, col. 848] assumed a bulbous form, thus losing sight of the mathematical principles which render the dome so constructively simple an architectural feature. [DOME.] Moreover, instead of being employed singly, domes were sometimes used in great profusion, there being, besides the principal dome, a number of subordinate ones, sometimes according and at others contrasting with it in shape. *Minarets* are another characteristic feature in the Asiatic varieties of Saracenic architecture; but for an account of them it will be enough to refer to the article MINARET. The long and slender forms of minarets being opposed to the swelling curves of domes, contributed not a little to that picturesqueness of outline which is so striking in buildings of later Saracenic style. The cut of the At-Meidan at Constantinople, given under MOSQUE, will serve as an illustration of the multiplication of domes and the application of the minaret, whilst the article itself will furnish some general information on the subject of mosques.



Mosque (Cathedral) at Cordova.

We may now briefly notice a few of the more characteristic existing examples of the style; beginning with those of Spain. Of these the oldest is the mosque at Cordova, which now serves as the cathedral of that city. It was the earliest structure of any importance erected by the Moors in Spain, having been commenced by the Caliph Abd-el-Ramhan, in 786 A.D., with the avowed intention that it should surpass in splendour the mosques of Baghdad, Damascus, and Jerusalem. It was completed in 796. Like all early Saracenic work it is characterised by a certain severity and massiveness of style. Byzantine architects are said to have been specially invited into Spain to superintend its construction. In its plan the original building bore a general resemblance to a basilica, but it was greatly altered about the close of the 10th century by El Mansour, who converted it into a parallelogram by adding eight aisles to the eastern side. As it now stands it is an insulated oblong building, extending 620 feet from north to south, including a spacious court at its north end or side. The interior presents almost a forest of jasper and other marble columns, upwards of 600 in number, and dividing the plan into nineteen aisles in one direction (350 feet in length), and thirty-five in the other. But it is disproportionately low as compared with its great extent, the height to the roofs being only about 34 feet. The arches are carried upon columns without entablatures as in Romanesque buildings. [ROMANESQUE ARCHITECTURE.] The interior presents a singular array of double, circular, and horseshoe arches, some of the upper ones being curiously interlaced. There is a great display of rich carving of a modified Byzantine character, and much of the peculiar tracery and diapering, as well as numerous inscriptions of the kind described above. The pointed arch does not occur; the domes are comparatively recent additions. In that division of the building appropriated to the imams and chiefs was the great *kibla*, or sanctuary (in which the Koran was deposited), an octagon covered with a cupola shaped out of a single block of stone; the *mihrab*, or pulpit, and the *maksura*, or khalif's seat. After the conquest of the city in 1236, by San Ferdinand, this mosque was converted into the cathedral, in consequence of which the character of the interior has been greatly injured by the erection of a Gothic choir in its centre. As a splendid work of a later epoch of the style, Cordova could once boast of the palace called the Az-zahrá, erected about the middle of the 10th century by the celebrated Abd-el-Rhaman III., the eighth Umeyyah sovereign of Spain. Of this edifice, which was at the distance of about two leagues from the city, nothing now remains to attest its former magnificence, except the descriptions given of it by Mohammedan writers, according to which it was adorned with 4000 marble pillars, and had walls and pavements of the same material. The sumptuousness ascribed to the edifice and its fountains and baths might pass for mere Oriental hyperbolism, were it not that the evidence still afforded by the Alhambra, and by parts of the Alcazar at Seville, removes the suspicion of exaggeration; or rather, the exuberant beauties revealed to us by the latter structures greatly surpass anything the most florid description can picture to the mind.

The Alhambra, the residence of the Moorish kings of Granada, is supposed by some to have been founded by Mohammed Ibn Alhamar, the first ruler, who reigned from 1238 to 1273; according to others, was begun by his successor Mohammed II. (1273–1302), or by Nasser, and completed by Abu-l-hejaj in 1348. This highly interesting and important monument of western Arabian architecture is now rendered comparatively familiar to us, by descriptions and drawings, and by geometrical and pictorial illustrations of its principal parts and decorations, not only in the elaborate works of Murphy, Jones, and Hassemer, but also in many drawings and publications of a more popular kind by Roberts, Lewis, and other able draftsmen, while several parts of the interior have been reproduced by casts and restorations in the Crystal Palace at Sydenham. Here therefore it need only be noticed briefly and generally: it is described, with cuts, under ALHAMBRA, in the GEOG. DIV.

The Alhambra was a fortress palace, the outer-walls of which enclosed an area 2500 feet long and 650 wide. Its superb palace has suffered alike from wilful destruction and from neglect, yet its ruins are among the most romantic and most interesting in the world. What is left of it consists of two great courts or halls and several of smaller size. Of these the richest and most impressive is the Court of the Lions, which extends 100 feet from east to west, and is 60 feet wide: yet impressive as it still is, and gorgeous as it must have originally appeared, it is really composed of only the most seemingly fragile materials—wood covered with stucco. Its general character and appearance will be best understood by the reproduction at the Crystal Palace; but it must be remembered in looking at the copy that whilst the original is of much larger size, the central fountain, from which it derives its name, is, in each, of the same dimensions. On each side of the Court of the Lions is a much smaller apartment, that on the north being known as the Hall of the Sisters, while on the south is the gorgeous Hall of the Abencerrages, reproduced of the actual dimensions by Mr. Jones at the Crystal Palace. At the east end stands the Hall of Judgment. Before the Hall of the Two Sisters are the Baths. West of the Court of the Lions, and at right angles to it, is the second great court, called the Court of the Alberca—an older and less ornamented building. There are other connected rooms and detached buildings to which it is sufficient to allude, while a third large court, probably a mosque, is said to have been removed to make room for the cold and formal palace erected by Charles V. adjoining the Court of the Alberca. The architectural character of the interior, on which almost exclusively the florid ornament is lavished, has been already spoken of, and the arches, pillars, tracery, diapering, &c., described. The Alhambra is considered, and justly, as the crowning work of Saracenic architecture in Europe; it marks a period when the style had reached the very verge of decorative propriety, and it is probable that any further progress would have been towards mere voluptuous excess, and that the decline would have been swift and certain. Other remains of Saracenic buildings are still numerous in all those parts of Spain which were occupied by the Moors, and some of them are of considerable interest. It is noteworthy, however, that the only approximation to a minaret, or to any of those light and lofty forms in which the Saracenic architects of the East delighted, is found in the Giralda at Seville; and this bears more resemblance to an Italian campanile, it being a square of 45 feet, and rising undiminished to a height of 185 feet: the upper and smaller portion was added in 1568.

The earliest of the Egyptian buildings of which any portions remain is the Mosque of Amrou at Old Cairo, begun about A.D. 642, but greatly altered, if not rebuilt, about 60 years later. It is a nearly square building about 390 by 360 feet, surrounded on each side by colonnades or arcades, the columns of which, 245 in number, were taken from Byzantine and Roman buildings. The arches, as is usual in arcades in the Saracenic buildings of the East, have tie-beams, in this instance of wood. Of the original ornamentation little is left. A more important example of the style is the great mosque erected by Ibn Tooloon at Cairo, towards the end of the 9th century, and which is still in a state of tolerable preservation. Like the preceding, it is a nearly square structure, the outer walls being 455 feet by 390; the great court, nearly 300 feet square, is said to have been designed by a Byzantine architect. Like all early Mohammedan buildings, it is built entirely of brick covered with stucco, and all the rich interior ornamentation is of stucco. The arches of the colonnade surrounding the great court are of the pointed horse-shoe form, and are borne on massive piers with attached shafts at the angles. The windows, mostly of pointed horse-shoe arches, are all filled with the pierced tracery described above, which is not only singularly graceful in design, but the effect of which is described as exceedingly cool and pleasing in such a climate. Other mosques in Cairo afford very interesting specimens of this style of architecture of a later date; as that of Barkook, erected about the middle of the 12th century, which has a fine dome, a lofty and very elegant minaret, and other ornamental features, and in which the pointed arch is employed with as much facility as in a Gothic cathedral. But a far more imposing building is the mosque of Hhasaneyn, or Hassan, which is of great size and height, very massive in construction, and is crowned by a noble dome and two very handsome minarets, each 280 feet high. The mosque of El Moyed, erected in 1415, is remarkable for the richness of its interior.

For the fall of the Moorish dynasty in Spain, the Mohammedans were to a certain extent recompensed by the conquest of the great Christian city and territory of Byzantium; and from that time dates a new variety of Saracenic architecture which had its origin in Constantinople. On the capture of Constantinople, Santa Sophia was converted by the conquerors into their chief mosque, and made their architectural model. The older Saracenic style indeed continued to be the basis of the new, but it was modified throughout by the Byzantine influence. The dome became a more and more prominent feature; ornamentation was applied with more economy, more grouped and massed, more simplified and less diffused. But the old Eastern exuberance found vent in various ways, while the taste and energy which served at once to direct and control it, became less and less apparent, and the style steadily deteriorated, though as long as vitality lasted, it exhibited gleams of a rich quaint fancy. The first mosque erected in Constantinople was built by Mahomet II., the conqueror of the city; and a large mosque is still shown as his; but very little remains of the original fabric. More perfect is the great mosque erected about the middle of the 16th century by Suleiman the Magnificent. Avowedly an imitation of Santa Sophia, it is yet larger, richer, and to an architectural eye, superior in form, the dome especially being higher and better proportioned. The great mosque, called At-Meidan, erected by Achmet in the first half of the 17th century, is remarkable among other things for its array of cupolas and its minarets. No less than thirty small domes surround the outer court, each bay of the arcade being surmounted by one. The mosque proper has a well-proportioned great dome (80 feet in diameter), flanked by four smaller domes, while (as will be seen from the cut in the article MOSQUE), several other small domes occur in different parts of the building. In this, as in the other Constantinopolitan mosques, the columns which support the horse-shoe arches of the arcades are fastened together by iron tie-rods. The great dome of this mosque is borne on four immense piers, which are faced with marble. The minarets are of very graceful form and proportions. The various ornamental details are pure in character, whilst they, as well as the general form of the building, show almost entire freedom from Byzantine taste. But this was the last great effort of Turkish architecture. European artificers soon after this began to be employed, and European fashions to be imitated, and the native style became proportionally debased.

SARACENS, a name improperly given by the Christian authors of the middle ages to the Mohammedans who invaded France and settled in Sicily. Concerning the etymology of this word there have been various opinions. Du Cange ('Glossarium,' *v.* 'Saraceni') derives it from "Sarah," the wife of Abraham; Hottinger ('Bib. Or.') from the Arabic word *saraca*, which means "to steal, to plunder." Forster, in his 'Journey from Bengal to England,' derives it from *sahra*, "a desert." But the true derivation of the word is *sharkeyn*, which means in Arabic "the Eastern people"—first corrupted into Saraceni (Σαρακηνοί) by the Greek, and thence into *Saraceni* by the Latin writers. Stephanus Byzantinus says that "Saraka is a region of Arabia, adjoining the Nabathæi, and the inhabitants are called 'Saraceni.'" Ptolemy (vi. 7) makes Saraka a city of Arabia Felix. The name Saraceni occurs in Pliny (vi. 28), and it seems that it began to be used about the 1st century of our era, and was applied to the Bedouin Arabs who inhabited the countries between the Euphrates and the Tigris, and separated the Roman possessions in Asia from the dominions of the Parthian kings. The description of the Saraceni by

Ammianus Marcellinus (xiv. c. 10) exactly corresponds with the habits of the Bedouins. In course of time it became the generic name of all the Arabian tribes who embraced the religion of Mohammed, and spread their conquests over the greater portion of Asia and Africa.

SARCOCELE (from σάρξ, flesh, and κήλη, a tumour) is the name of a disease by which the testicle becomes altered from its natural structure and converted into a hard flesh-like substance. The term however is of such general import, that there are few diseases of the testicle which may not be included under it; accordingly the older writers called all indurations and enlargements of this organ sarcoceles, whether they were of a benign or of a malignant nature. In modern phraseology the term is restricted to certain chronic enlargements and indurations of the body of the testis, of a perfectly benignant character, but inconvenient on account of their size and weight. These swellings may continue for years without undergoing any visible change, or a sudden increase in their bulk may arise, and the testicle be converted into a painful, ulcerated, and incurable mass of disease. Sarcocele may be distinguished from hydrocele, the disease which most nearly resembles it, by its hardness, weight, and want of transparency; but occasionally the two diseases are met with together, and this compound affection is called hydrosarcocele. With respect to the treatment of sarcocele, various and rather opposite remedies have at times proved successful. When the enlargement is accompanied by pain or any degree of inflammation, leeches, hot fomentations, and poultices applied externally, with the administration of an emetic, and the adoption of a general antiphlogistic regimen, would seem to be indicated. When the disease is altogether chronic, stimulating lotions, liniments, or ointments may be applied to the swelling. In either case, the use of a suspensory bandage, or bag truss for the support of the part should not be neglected. If these means fail in arresting the progress of the disease, extirpation of the gland must be had recourse to.

SARCOCOLLIN ($C_{22}H_{19}O_{10}$?). A gummy matter, extracted from the sarcocolla of commerce, the dried juice of the *Penea mucronata*. It possesses a peculiar but feeble odour, and a bitter-sweet taste. It is sparingly soluble in water, but readily so in alcohol. Nitric acid transforms it into oxalic acid.

SARCOMA is a morbid tumour whose tissue is fleshy and moderately firm. Several species of sarcoma were described by Mr. Abernethy in his 'Classification of Tumours,' such as the common vascular sarcoma, the adipose or fatty kind, the pancreatic, the mammary, &c. Some of these still retain the same names, but in general the term sarcoma has no other meaning in surgical works than the indefinite one already given, and includes all fleshy tumours that are not cancerous, or medullary, or melanotic. [TUMOUR.]

SARCOPHAGUS, a word derived from the Greek signifying *flesh-eater*, but used to designate any kind of coffin, especially large ones of stone. This name was given from sarcophagi being originally made of a kind of stone from Assos in Mysia, supposed to be *alumens chisti*, or a kind of pumice stone, which was fabled to consume the entire body, with the exception of the teeth, in the space of forty days. (Pliny, 'N. H.,' ii., 98, xxvi. 27.) The term was, however, applied at the time of the Roman Empire to all kinds of stone coffins. (Juvenal, x., 172; Dig., 34, tit. i., s. 18, s. 5; 'Orellius Inscript.,' Nos. 194, 4452, 54.) The earliest sarcophagi are the Egyptian, called in the hieroglyphs *teba*, or chest, and found from the time of the pyramids [PYRAMIDS] till the 1st century A.D. Those of the early dynasties were sculptured in shape of a square chest, or edifice, and left plain or else only ornamented with two leaves of the lotus. Those of the 18th and following dynasties were of different shapes, the most usual being that of an Egyptian mummy swathed, dividing into two parts lengthwise, the cover formed by the front, and the chest by the back of the figure—the two fixing by mortices and grooves, holes for which were cut in the stone. The coffins of this period were principally of red granite, and ornamented with inscriptions or scenes relating to the myth of Osiris, or the passage of the Sun through the lower hemisphere, or regions of the night and darkness. The most remarkable of this period are the arragonite or oriental alabaster sarcophagus of Seti I., in the Soane Museum, and that of Rameses III., in the Louvre, the cover of which is in the Fitzwilliam Museum at Cambridge. At the period of the 26th dynasty, the sarcophagi were generally made of basalt; although a coarse red granite, black or white marble was occasionally used. The hieroglyphic legends of this age are often chapters extracted from the Ritual of the Dead. The last of the royal sarcophagi is that of Nekhtherhebi, or Nectanebes I., in the British Museum, made of a fine breccia, and sculptured with scenes of the passage of the Sun. This was formerly at Alexandria, and supposed upon very insufficient grounds by some to have been the tomb of Alexander the Great. Recent discoveries have shown that the Phœnician kings were buried in sarcophagi of basalt or alabaster, of a mummied shape like the Egyptians, although different in treatment and art. The most remarkable of these is that of Esmunazar, king of Sidon, inscribed with a long Phœnician inscription, and supposed to be of about B.C. 574. The Persian monarchs were also buried in sarcophagi, and one of those of the kings of Judah, a plain rectangular chest, decorated with a simple floral ornament of vine branches, is in the Museum of the Louvre. Rude sarcophagi were also used by the Lycians and other Græco-barbaric people of Asia Minor.

In Asiatic and European Greece many sarcophagi have been found, but few, if any, earlier than the Roman Empire, and generally of the 1st and 2nd century A.D. These are of the same character as those discovered in the Roman columbaria, consisting of rectangular chests about 8 feet long, 3 feet high, and as many broad. The covers are often in shape of a pent roof, or ornamented with figures of the deceased in full relief. They are richly decorated with bas-reliefs, at an earlier period, of many figures representing mythological subjects, but at a later with festoons of flowers, fruit, and arabesques, with small figures. A still larger class than the Greek are the Etruscan, none of which, from their style of art, seem older than the middle of the 4th century B.C., and are made of peperino, alabaster, or terra-cotta, generally having on their covers a full-length recumbent figure of the deceased leaning on the elbow as if on a couch at a feast. The chests are decorated with reliefs, representing Greek myths, treated in the Etruscan manner, with the names of the persons represented in the Etruscan language. Those found in the tombs of Volterra and Chiusi are of arragonite or marble, of small dimensions, about 14 inches long by 3 inches broad, and 1 foot 6 inches high, and are rather cinerary urns, as they contain only the ashes of the dead. The Roman sarcophagi, at the time of the republic, appear to have been plain architectonic chests, as shown by those of the Scipio family, but under the empire they became more richly ornamented, like the Etruscan, with recumbent figures on the cover and bas-reliefs of mythological subjects, allusive to the life or death of the person buried, as Prometheus, Orestes, and Ganymede. These sarcophagi continued till the 6th and 7th century, when arabesques were introduced, and two remarkable ones of the first period of Christian art are those of St. Constantia and St. Helena of red porphyry, ornamented with bas-reliefs, representing triumphs and processions, at present in the Vatican. At a later period Christian sarcophagi are ornamented with subjects taken from the Old and New Testament. Stone chests or sarcophagi were also used for interment by the Gaulish tribes, and their use for the sepulture of distinguished persons has been continued till the present day.

(De Rougé, *Monuments Égyptiens du Musée de Louvre*, 8vo, Paris, 1855; Duc de Luynes, *Le Sarcophage d'Esmunazar*, 4to, Paris, 1856; Micali, *Storia d'Italia*, Fir., 1832.)

SARCOSINE ($C_6H_7NO_4$). An organic alkaloid, belonging to the same class of bodies as urea and sugar of gelatine. It is procured by adding hydrate of baryta to a boiling saturated solution of creatin. On filtration a colourless liquid is obtained, containing caustic baryta and sarcosine. Through this liquid a current of carbonic acid gas is passed whilst it is gradually heated to boiling. The filtered liquid becomes syrupy on evaporation, and finally deposits large crystalline leaves of sarcosine, which is purified by conversion into sulphate, agitation with alcohol, solution in water, and final treatment with carbonate of baryta. The filtered liquid being then evaporated upon the water-bath deposits crystals of pure sarcosine, which are colourless and transparent, very soluble in water, slightly so in alcohol, and insoluble in ether. They fuse at a temperature somewhat above 212°, and volatilise without residue.

Sarcosine is isomeric with lactamide, urethane, and alanine. It does not affect vegetable colours, but forms salts with acids. The sulphate of sarcosine has the formula $C_6H_7NO_4, SO_3HO + aq.$, that of the double platinum salt is $C_6H_7NO_4, HCl, PtCl_2 + 2\ aq.$ The solution of the sulphate reacts strongly acid.

SARDONICUS RISUS, a convulsive affection of the muscles of the face, in which the lips are drawn involuntarily apart, so as somewhat to resemble the expression of the countenance in laughter. The name is derived from a species of ranunculus that grows in Sardinia, called Herba Sardonica, or Sardoa, which is said to produce this affection in those who eat it.

Risus Sardonicus is observed as an effect of certain vegetable poisons, such as the *Ranunculus sceleratus* of Linnæus, but is more frequently met with as one of the symptoms of tetanus, or locked-jaw, or as an attendant on other convulsive affections.

The term is employed figuratively to denote that forced laugh by which persons sometimes endeavour to conceal their real feelings.

SAROS, NEROS, SOSOS. These names are from the fragments left of Berosus, who says that the Chaldæans had three astronomical periods so called, the saros of 3600 years, the neros of 600 years, and the sosos of 60 years. Of the two latter we know nothing more, and as to the saros, the duration given by Berosus is either entirely wrong, or else subsequent writers have taken another Chaldæan period, which is neither of the three above, and applied the term saros to it. Geminus (ch. 15) mentions that the Chaldæans had found a period of 669 months, or 19,756 days (so the text stands after an emendation by Bouillaud). Ptolemy mentions the same period, and Pliny (lib. ii., c. 13) remarks relative to it, that eclipses return again after a period of 223 (the third of 669) months; but the text here again was corrupt, until Halley ('Phil. Trans.,' No. 194) restored the true reading, which was afterwards confirmed by manuscripts. To complete the misfortunes of this period, Suidas has the word Saros, but it was omitted from his Lexicon either by mistake or faultiness of manuscripts, until Dr. Pearson restored it ('Exp. of the Creed,' 1683, fol. 59, according to Weidler), and even then it gives 222 months instead of 223, which was again corrected by Halley. In the time of Riccioli, Geminus and Ptolemy were the authorities cited on this period, and the name Saros was not applied to it. Many writers (Costard for example) confound it with the Metonic period of 235 lunations, which is a totally different thing: others again, as Geminus, and even Riccioli, appear to consider it as a period for the determination of the lunation or month; and perhaps the assertion made by some others, that the Chaldæans were in possession of the Metonic cycle, may be another confusion between the latter and the saros.

Leaving the authorities on the subject, we know [MOON] that 223 average intervals between full moon and full moon make up very nearly 242 nodical months, or passages of the moon from one node to the same again. Now since the eclipses entirely depend upon the manner in which the full and new moons take place relatively to the node, it is obvious that if 223 lunations were exactly 242 nodical months, and if the sun's and moon's orbits were truly circular, and their motions uniform, all the eclipses of one set of 223 lunations would be produced again precisely in the same order during the next 223; that is, if there were (say) an eclipse of the sun during the 47th lunation, reckoning from a given full moon, there would necessarily be another in the (47 + 223)rd, or the 270th lunation, and so on.

All these suppositions are near enough to the truth to make this sequence of eclipses very nearly take place. For since 223 lunations make 241·029 sidereal months, 238·992 anomalistic months, and 241·999 nodical months, it is obvious that at the end of a saros the moon is in the same position with respect to the sun, nearly in the same part of the heavens, nearly in the same part of her orbit, and very nearly indeed at the same distance from her node as at the beginning of the period. Now 223 lunations make 6585·32128 days, or 6585 days, 7 hours, 42 minutes, and 38 seconds; or 18 years (of 365 days), 15 days, 7 hours, 40 minutes, and 38 seconds. Consequently a saros of five leap years is 18 years, 10⅓ days, and one of four leap years is 18 years, 11⅓ days, nearly. The Chaldæan period is 6585⅓ days; and to avoid fractions they appear to have put together three such periods, making 19,756 days, and 669 lunations. From what has been said above, it might be inferred that the rotation of the moon's node is made in nearly a saros; and in fact that revolution does take 18·6 years.

It is to be observed, however, that the end of each saros is not in the same part of the day as the beginning, which is of consequence as to the solar eclipses, though not so as to the lunar, and still more does the inexactness of the period affect the former. For a saros contains 241·998659 mean nodical revolutions; so that if the moon be in her node at the beginning of a saros, she will want ·001341 of a revolution of being in her node at the end of it. This is about 29′, nearly the moon's diameter, which makes it sometimes happen that a lunar eclipse which takes place in a certain lunation of one saros does not take place in the same lunation of the next, and very often causes the same as to a solar eclipse. And the effect must be that at last the eclipse of any lunation is destroyed, by the accumulation of these errors of 29′ each time. Nor do the circumstances of one saros precisely resemble those of another until a longer period of about 746 such periods has elapsed. But in the same manner that eclipses are removed out of one lunation by the inexactness of the period, they are carried into another. There are about 70 eclipses in each saros, 30 lunar and 40 solar.

The Metonic cycle of 235 lunations gives 255·021 nodical months, which is not near enough to a whole number to produce anything like a return of similar eclipses. But it is, as explained [MOON], near enough to an exact number of years to restore the full moons to the same days of the year, or the preceding or following days. The Metonic cycle is a chronological period; that is, portions of time measured from a given epoch, and each equal to 19 years, are used in chronology. But the Saros is not a chronological period, but only a portion of time with any arbitrary commencement. Hence the student must not look in works on chronology for any information upon it.

(Riccioli, *Alm. Nov.*; Weidler, *Hist. Astron.*; Bouillaud, *Astron. Philol.*; Ferguson's *Astronomy*.)

SARSAPARILLA. [SMILAX.]

SASSAFRAS, *Medical properties of.* The tree which yields this substance is the *Sassafras officinale* (Nees) (*Laurus Sassafras*, Lin.); a native of North America, occurring from Canada to Florida. It is said to grow in Mexico, and Martius mentions it as a part of the Materia Medica of Brazil; but it is probable that it was introduced from Florida. Though Martius distinctly enumerates *Laurus Sassafras* (Linn.) among the medicinal plants of Brazil (Spix and Martius's 'Travels in Brazil,' English translation, London, 1824, vol. ii. p. 96); yet recent writers state the Brazil sassafras to be the produce of *Nectandra cymbarum* (Nees), the *Ocotea amara* of Martius. (Mart. in Buchner's 'Report,' xxxv. 180.) This point is worthy of careful determination, if Martius' statement be correct, that the bark of this tree is an ingredient in the famous woorary poison. Sassafras nuts are probably the produce of one or two species of *Nectandra*. The bebeerine, an important anti-febrile medicine, is the bark of *Nectandra Rodici* (Schomb.). It is a constituent, probably, along with quinia, of Warburg's fever drops. The root is the officinal part in the London Pharmacopœia; but the whole plant possesses the aromatic odour common to the *Laurineæ*, and some assert that the bark of the stem and branches is stronger than that of the root; but this seems to be an error. The root, invested with the bark, comes to Europe in pieces sometimes 2 feet long, and from the thickness of an arm to half a foot in diameter, irregularly bent, knotty, and with a light, soft, porous wood. The bark also occurs detached from the wood in pieces two or three inches long, from one and a half to two inches broad, sometimes rolled outwards, but more generally curved inwards; of a dirty grey or brownish colour externally, and a fungoid surface of a reddish colour internally. The taste is sharp, acrid, aromatic, and, as well as the odour, resembles fennel.

The chief constituents are: volatile oil, resin, and extractive. The oil is the most active. It may be obtained by distillation. Ten pounds of the root yield two and a half drachms. The specific gravity is 1·094. It consists of two oils, separable by water, in which the one floats and the other sinks. By time or a low temperature, it deposits a stearopten, or crystals of sassafras camphor.

Sassafras acts as a stimulant to the circulation, especially of the capillaries, causing an increased secretion from the skin, if the person be kept warm, or from the kidneys, if cool. Should these organs fail to be influenced by it, heat and general excitement, with headache, are the results. It is of unquestionable utility in gout and rheumatism, but its activity is generally destroyed by the improper mode of administering it. Decoction dissipates the volatile oil, and is a most objectionable preparation. Infusion or a tincture may be used, or the volatile oil rubbed up with sugar. Other species of Sassafras are used in India and Java. Sassafras tea is sold in the streets of London under the name of saloop.

SATELLITE (*satelles*, an attendant soldier or guard), a name given to the smaller planets which accompany and revolve round the larger ones. With this exception, that the rotation of a satellite round its own axis is made in the same time as its orbital revolution round its primary, in every case in which it has yet been fully made out that there is a motion of rotation, there seems to be no circumstance which can be pointed out in which the satellites have any distinctive peculiarities. The earth has one satellite [MOON], JUPITER has four, SATURN eight, URANUS six (according to William Herschel), though the existence of four only has yet been established, and NEPTUNE one. See also GRAVITATION, SOLAR SYSTEM, ASTRONOMY.

SATIN. [SILK.]

SATIRE is properly a species of Roman poetry, and must not be confounded with the Satyric drama of the Greeks. The Latin word *Satura* or *Satira* appears to have originally signified a collection of various things, and accordingly this name is applied to food composed of various ingredients, and also to a law consisting of several distinct particulars of a different nature. (Festus, s. v., Diomed. iii., p. 483, ed. Putsch.) The Roman satire is first mentioned as a kind of dramatic performance (Liv. vii., 2), and appears to have been, like the early Atellanæ Fabulæ, only a rude improvisatory farce, without dramatic connection, but full of raillery and wit. This species of composition arose from the practice, which has prevailed in Italy from the earliest times to the present day, of the country people making rude extempore verses in ridicule of one another at various festivals, and especially at the time of the vintage. Such were the Fescennini verses, which Macrobius tells us ('Saturn.,' ii., 4) were sometimes written as satires upon persons. The old dramatic Saturæ continued to be performed on the Roman stage till a late period, under the name of Exodia, which were laughable interludes in verse, and were performed between the different Atellane plays.

The name of satire was afterwards limited to a species of poetry peculiar to the Romans, in which Ennius is said to have been the first writer. The satires of Ennius appear to have been so called because they were written on a variety of subjects, and in many different metres; but as hardly any fragments have come down to us, we know very little of the subjects of which they were composed. Lucilius however was the first who constructed satire on those principles of art which were considered in the time of Horace as essential requisites in a satiric poem. Lucilius principally used the hexameter metre, which was afterwards almost exclusively employed by the satiric poets. His poems were not only satires upon the vices and follies of mankind in general, but also contained attacks upon private individuals. They formed the model on which Horace wrote his satires. His easy temper and happy disposition, as well as the principles of the Epicurean philosophy, led him to attack the foibles and follies of mankind in a style of playful raillery, which forms a striking contrast to the severe invectives of Juvenal. The increased corruption of morals at Rome under the early emperors, and the cruel punishments which had been inflicted by Domitian upon the wise and the good, naturally led Juvenal to attack the vices of his age with severity and vigour. The works of the other Roman satirists are lost, with the exception of Persius and a few verses on the banishment of the philosophers by Domitian, which are ascribed to Sulpicia, who is supposed by some writers to be a contemporary of Tibullus, and by others of Ausonius.

SATISFACTION (in Law), is said to exist where a party, having a right of action, accepts from the party against whom he has it, a certain and valuable thing, or the performance of a certain and beneficial act, in lieu of his right of action. If the action is afterwards brought, the satisfaction may be pleaded in bar of it. Satisfaction may exist as to actions in which damages are recoverable, and as to some others; but it cannot operate so as to dispense with the performance of a covenant under a deed, as a deed can only be made void by an instrument of the same nature. Where, however, a right of action upon the deed has vested, as in the case of a breach of covenant to repair, to pay rent, &c., there may be satisfaction. The satisfaction, to be valid, must have been accepted by the party who has the right, and must have proceeded from the party who is liable.

Nothing which is paid or done to a third party, or proceeds from him, can operate as a satisfaction. It must also be certain, that is, definite as to time, &c., and available; thus where the satisfaction is by mutual agreement, it must be such an agreement as an action may be maintained upon. It must be valuable; by which it is understood not only that there can be no satisfaction consequent of a thing which has no value, as, for instance, a rush; but also that the value must be at least not obviously inferior in amount to that for which it is given, such as a payment of a less sum of money at the same or a subsequent day as that on which a greater is due. Although if there are advantageous circumstances attendant on the payment of a less sum, this may operate as satisfaction. But the giving of a horse or a statue may be a satisfaction of a claim for a sum of money, if accepted as such, though the horse or statue be in reality of less value than the money.

A negociable instrument may operate as a satisfaction of a debt; and if the party who accepts it, by his own negligence fail to recover upon it, the debtor will nevertheless continue discharged. The performance must be actually executed; a mere endeavour, or a readiness to perform, such as a tender of money, or a part performance, cannot operate as a satisfaction. It must be beneficial; thus where one has made a forcible entry on the lands of another, it is not a satisfaction for the wrongful entry to permit that other to re-enter. In an action for trespass and taking cattle, a mere re-delivery of the cattle is not a satisfaction, though their conveyance to another place, and redelivery there, may be so. The benefit also must be one partaking in some shape of a pecuniary character. It must either be money, or capable of being measured by money. Thus a submission before certain persons made in pursuance of the order of a court-martial, or an acknowledgement of the injury and prayer for forgiveness kneeling, though a satisfaction in honour, is not such satisfaction as to deprive the party of his right to damages. Satisfaction to one of several plaintiffs is a bar to all: and satisfaction by one joint wrongdoer discharges the others. (Com., 'Dig.,' tit. 'Accord.')

SATRAP (σατράπης) was the name given to the governor of a province of the Persian empire. He was appointed by the king, and was responsible alone to him. Such a system of government has always existed in the large Asiatic empires; but the advantage which the Persian system had over many others of a similar kind, was the careful separation made between the civil and military powers. The governors of the garrisons and the commanders of the troops were independent of the satraps, and responsible only to the king. The duties of the satraps are briefly defined by Xenophon to consist in governing the inhabitants, receiving the tributes, paying the garrisons, and attending to whatever else is necessary. ('Cyrop.,' viii. 6, § 1-3.) In the later times of the Persian empire, it became the custom to appoint the satraps to the command of the troops also, especially if they were members of the royal family. In this manner the younger Cyrus was appointed satrap of one of the western provinces of Asia Minor, and at the same time general of all the forces which assembled in the plain of Castolus. (Xen., 'Anab.,' i. 1, § 2.) The practice of uniting the civil and military powers in one person, and the greatness of the command entrusted in some cases, was also dangerous to the royal power. An instance of this kind occurs as early as the time of the first Darius, in the case of Orœtes, who was governor of Phrygia, Lydia, and Ionia, and was so powerful that Darius dared not proceed openly against him. (Herod., iii. 127.) Subsequently this practice became still more frequent; Cyrus had the command of the greater part of the western provinces of Asia Minor; and after his death, Tissaphernes was allowed to hold them in addition to his own. From this period we frequently read of revolts of the satraps, and many of them became quite independent of the king of Persia. (Heeren's 'Asiatic Nations,' vol. i.)

SATURATION, a term applied in chemistry to denote two widely different phenomena: namely, first to the solution of the greatest possible quantity of any substance in a liquid medium; and, secondly, to the neutralisation of a base by an acid or of an acid by a base.

When common salt, and indeed most other saline and many vegetable bodies, are added to water until it ceases to dissolve them, the solution so obtained is termed a saturated solution of the substance dissolved.

Saturation of this kind may exist with regard to one body and not to another; thus water saturated with common salt will still dissolve sulphate of soda, and *vice versâ*; so also a saturated solution of common salt will dissolve sugar. The saturating power of bodies is in many cases greatly influenced by heat, while in others variations of temperature produce but little effect: thus cold water will take up nearly as much common salt as hot water; but sulphate of soda is more soluble in hot water than in cold, and hence it is that a saturated hot solution of this and many other salts deposits crystals on cooling. Cold water, on the contrary, dissolves more lime than hot, and a saturated solution prepared with water at about 32° holds nearly twice as much lime in solution as one prepared at 212°, and when the cold prepared solution is heated lime is deposited. This, however, is a case of much rarer occurrence than the contrary one.

As instances of the second kind of saturation, the following may be adduced:—If to a solution of carbonate of potash any strong acid, such as the sulphuric, be added until effervescence ceases, the potash is said to be saturated. In like manner, if a solution of caustic soda be added to nitric acid until the latter be exactly neutralised, the acid is said to be saturated. In these cases the point of saturation is determined by the use of papers stained with different vegetable colours; if, for example, too much carbonate of potash should have been added to the nitric acid to saturate it, its presence will be indicated by turning paper coloured yellow with turmeric, brown; while, on the other hand, excess of acids is in general ascertained by paper stained blue with litmus, which is rendered red by the action of acids.

By these means a very important process in the manufacture of soap and glass is conducted; it is termed *alkalimetry*, and employed for ascertaining the strength of different samples of the carbonates of potash and soda, so largely used in glass- and soap-making. Sulphuric acid diluted to a known extent is added to the alkaline solutions, and when they affect neither blue nor yellow paper, the saturation is perfect, and the purity and strength of the alkalies are determined. [ALKALIMETRY.]

SATURDAY. [WEEK.]

SATURN. The name of one of the old planets, the largest of all the bodies of the solar system, except the Sun and Jupiter. It is encompassed by three rings, unconnected with the planet, but revolving around it. It is also accompanied by eight satellites.

The apparent semi-diameter of Saturn, at the mean distance of the planet from the earth, is about 16″·4. The real diameter, that of the earth being represented by unity, is about 79,000 miles. The mean density is about 0·55 of that of the Sun, or $\frac{1}{7}$th of that of the Earth, and the mass of the planet is about $\frac{1}{3512}$, the Sun's mass being represented by unity. It revolves on its axis in 10 hours, 29 minutes; its equator is inclined to the ecliptic at an angle of 31° 19′. Its light and heat are to the light and heat received by the earth as 11 to 1000. The following are the elements of its orbit:—

Epoch 1801, January 1, 12th hour, mean astronomical time at Greenwich. Semi-axis major, 9·5387861, that of the Earth being represented by unity.

Excentricity, ·0561505; its secular diminution (diminution in 100 years) ·000,312,402.

Inclination of the orbit to the ecliptic, 2° 29′ 35″·7; its secular diminution, 15″·5.

Longitudes from the mean equinox of the epoch: (1) of the ascending node, 111° 56′ 37″·4; its secular increase (combined with the precession), 3070″; (2) of the perihelion, 89° 9′ 29″·8; its secular increase (combined with the precession) 6950″; (3) of the planet (mean), 135° 20′ 6″·5.

Mean sidereal revolution in 365¼ days, 43996″·13; sidereal revolution, 10759·2198174 mean solar days.

The discovery of the ellipticity of Saturn is due to Sir William Herschel, who concluded, from his observations, that the polar is to the equatorial diameter as 10 to 11. On a subsequent occasion he was led to suspect an irregularity in the figure of the planet, but the researches of Bessel, and also those of Mr. Main,* late first assistant at the Royal Observatory, Greenwich, have proved beyond all doubt that the form of the planet is strictly spheroidal.

When viewed in the telescope the planet Saturn appears to be diversified with belts extending across his disc in a direction parallel to his equator. It was by watching the changes in the appearance of these belts, that Sir William Herschel succeeded in discovering the motion of the planet on his axis, and in determining the time of a complete rotation.

The satellite of Saturn which was first perceived is the sixth in the order of distance from the primary. Its discovery was effected by Huyghens in 1655. Four other satellites were subsequently discovered by Cassini in the same century. These five satellites were named the first, second, third, fourth, and fifth, reckoning according to their distance from the primary. In 1789, two additional satellites were discovered by Sir William Herschel. Both of these satellites were found to revolve within the orbit of the *first* of the five satellites previously discovered. They ought therefore in accordance with the prevailing nomenclature, to be designated as the first and second satellites, but this would have rendered a revision of the names of the earlier satellites indispensable. The Herschelian satellites however were usually styled the sixth and seventh, reckoning *inward* in the order of distance from the primary. To remedy the imperfection which thus arose from confounding the order of discovery with the order of distance, Sir John Herschel has recently proposed to apply to the satellites the names of the Titanian divinities,—Japetus, Titan, Rhea, Dione, Tethys, Enceladus, Mimas, commencing with the most distant satellite. This nomenclature has been generally adopted by astronomers.

On the 19th of September, 1848, an eighth satellite of Saturn was discovered by Mr. Bond, at the Observatory of Harvard College, Cambridge, U.S.; and also independently, on the same evening, by Mr. Lassell at his Observatory near Liverpool. In conformity with Sir John Herschel's nomenclature it has been called Hyperion. It ranks the seventh in the order of distance from the central body. The following table will be found useful :—

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* Now director of the Radcliffe Observatory, Oxford.

Name of Satellite.	Order of Distance from the Planet reckoning outward.	Period.	Mean Distance from the Planet in terms of the Planet's Radius.	Date of Discovery.	Discoverer.
		d. h. m. s.			
Mimas . .	1	0 22 37 22·9	3·3607	1789	W. Herschel.
Enceladus . .	2	1 8 53 6·7	4·3125	1789	W. Herschel.
Tethys . .	3	1 21 18 25·7	5·3396	1684	Cassini.
Dione . . .	4	2 17 41 8·9	6·8398	1684	Cassini.
Rhea . .	5	4 12 25 10·8	9·5528	1672	Cassini.
Titan . . .	6	15 22 41 25·2	22·1450	1655	Huyghens.
Hyperion . .	7	22 12?	28 ±	1848	Bond and Lassell.
Japetus . .	8	79 7 53 40·4	64·3590	1671	Cassini.

The periods and mean distances inserted in the foregoing table have been taken from Sir John Herschel's 'Outlines of Astronomy.' The period and mean distance of Hyperion have not yet been determined with sufficient precision.

The light of Japetus has been found to be subject to a variation depending on the position of the satellite in its orbit. From this circumstance it has been inferred, with a strong degree of probability, that the satellite effects a complete rotation on its axis in the same time as that in which it revolves around its primary, as in the case of the moon revolving around the earth. By far the most considerable of the satellites is Titan, which Sir John Herschel considers may be equal in magnitude to the planet Mars.

The appearance which Saturn presented to Galileo, when he first turned his telescope on the planet, was utterly inexplicable. The illustrious philosopher remarked, that the planet seemed to consist not of one but of three bodies, which almost touched each other and always maintained the same relative position. The three bodies were arranged in the same straight line, the largest body being in the centre, and the two others on the east and west sides of it. Pursuing his observations he found that the two lateral bodies continued gradually to diminish, until at length, after the lapse of about two years, they entirely vanished, leaving the planet quite round. He now felt much alarmed, lest those who derided his discoveries as optical illusions having no real existence, should adduce this mysterious transformation of the planet in support of their views. Writing to Welser on December 4, 1612, he says, "What is to be said concerning so strange a metamorphosis? Are the two lesser stars consumed after the manner of the solar spots? Have they vanished and suddenly fled? Has Saturn perhaps devoured his own children? Or were the appearances indeed illusion or fraud, with which the glasses have so long deceived me, as well as many others to whom I have showed them? Now, perhaps, is the time come to revive the well nigh withered hopes of those who, guided by more profound contemplations, have discovered the fallacy of the new observations, and demonstrated the utter impossibility of their existence. I do not know what to say in a case so surprising, so unlooked-for, and so novel. The shortness of the time, the unexpected nature of the event, the weakness of my understanding, and the fear of being mistaken, have greatly confounded me."

It was reserved for Huyghens to ascertain the real nature of the appendage with which Saturn is furnished. He originally announced his discovery in the form of an enigma, in a pamphlet entitled 'De Saturni Luna Observatio Nova,' published in 1656. The logogriphe ran thus :—

aaaaaaa ccccc d eeeee g h iiiiiii llll mm nnnnnnnnn
oooo pp q rr s tttt uuuuu.

In 1659 he published a work entitled 'Systema Saturnium,' in which he reveals the real nature of his discovery, and gives a detailed explanation of the various circumstances connected with it. Restoring the letters of the logogriphe to their original places, they now stood thus :—

Annulo cingitur tenui plano, nusquam cohærente, ad eclipticam inclinato ;

or, as thus translated :—

The planet is encompassed by a slender flat ring, everywhere unconnected with its surface, and inclined to the ecliptic.

Nothing can be more convincing or beautiful than the explanation which this theory affords of the various phenomena presented by the planet. When the position of the planet in its orbit is such that the plane of the ring passes through the sun, the edge only of the ring is exposed to the solar rays, and the extent of the illuminated surface being very small, it is incapable of producing a sensible impression on the visual organ. In this position, then, the ring is invisible, and the planet presents a round appearance like the sun or the full moon. The ring also disappears when its plane passes through the earth; for although one of its sides may then be illuminated by the sun, it is only the edge which is turned towards the observer. Besides these two causes of disappearance, which are of a transient nature, and render the ring invisible only for a few days at most, there is a third cause, which generally continues in operation during a longer period of time, and produces a more lasting effect. When the planet is so situated that the plane of the ring passes between the earth and the sun, the unenlightened side of the ring is then turned towards the earth, and consequently during the whole time that the planet is in this position (which frequently extends to several months) the ring will be invisible. The same theory affords an equally satisfactory account of the different phases assumed by the appendages of the planet during the period of its visibility. It is manifest that when the plane of the ring passes through the sun, and when consequently the ring ceases to be visible, the planet, if viewed from the sun, would appear in the node of the ring. When the planet revolves from this position, the sun commences to ascend above the plane of the ring, and the latter in consequence becomes visible in the form of a very elongated ellipse, gradually opening out in breadth. The ellipse continues to approach towards a circular form until the planet has reached a distance of 90° from the node of the ring, when the elevation of the sun above the plane of the ring has attained its maximum. The ring henceforth begins to contract, and the same succession of appearances in a reverse order will obviously ensue as the planet revolves towards the opposite node, where the ring again will cease to be visible. The ring will therefore complete the cycle of its phases in a period equal to half a revolution of the planet, or in about fifteen years. The appearances will not be materially different whether the ring be viewed from the earth or the sun, except during the time that the planet is in the vicinity of either of the nodes of the ring. At such a juncture, the combined motions of the earth and the planet may cause the plane of the ring to pass more than once through the earth, and the ring may in consequence disappear and reappear twice before its plane has entirely swept over the terrestrial orbit.

Huyghens was originally under the impression that the plane of the ring is parallel to the equator, and he consequently supposed its inclination to the ecliptic to be 23° 30′. On a subsequent occasion, however, he determined the inclination by actual measurement in conjunction with Picard and he found it to amount to 31°. Huyghens also fixed the ascending node of the ring in 170° 30′ of longitude. Several succeeding astronomers determined the elements of the ring. The most recent as well as the most complete investigation of the subject is due to Bessel. The conclusion at which he arrived was that in the beginning of the year 1800 the longitude of the ascending node of the ring was 166° 53′ 8″·9 and that the inclination of its plane to the ecliptic was 28° 10′ 44″·7. He also found that the node of the ring retreats upon the plane of the ecliptic at the rate of 46″·462 annually.

In 1675 Cassini found that the ring around Saturn consists in reality of two distinct rings separated from each other by a dark interval. This interesting fact was subsequently established beyond doubt by Sir William Herschel. The following are the dimensions of the planet and the two rings as assigned by M. Struve :—

Exterior diameter of the exterior ring . . .	40″·095
Inner diameter of the exterior ring	35″·289
Exterior diameter of the interior ring . . .	34″·475
Interior diameter of the interior ring . . .	26″·668
Equatorial diameter of Saturn	17″·991
Breadth of the exterior ring	2″·403
Breadth of the division between the rings . .	0″·408
Breadth of the interior ring	3″·903
Distance of the interior ring from the ball . .	4″·339
Equatorial radius of Saturn	8″·995

These measures are supposed to refer to the mean distance of the planet from the sun. At such a distance an object which would subtend an angle of only 1″ would measure 4387 miles. This would give 78,927 miles for the diameter of the planet. The absolute dimensions of the rings will of course bear a similar proportion to their respective angular measures. Thus, it will be found that the diameter of the exterior ring amounts to 175,928 miles.

The thickness of the rings around Saturn would seem to be very inconsiderable. This is plainly indicated by the circumstance that when the edge of the ring is turned towards the observer, it is generally found to be invisible, even when the most powerful telescopes are directed towards it. From certain lucid protuberances which Sir William Herschel remarked upon the ring, he was led to suspect that it had a rotary motion around the planet. A closer scrutiny of the phenomenon confirmed this impression, and he finally concluded that the ring effects a complete rotation around the planet in a period of 10h. 32m. 15s·4.

On the 15th of November, 1850, Mr. Bond, Director of Harvard College Observatory, Cambridge, U.S., discovered a third ring around Saturn, situated between the interior of the two rings already discovered, and the body of the planet. The same phenomenon was discovered by Mr. Dawes on the 19th of the same month, and, of course, before intelligence of Mr. Bond's discovery had reached England. The new ring is much fainter than either of the two exterior rings. Its breadth is equal to about two-fifths of the interval between the interior bright ring and the planet.

It turned out, soon after the discovery of the faint ring by Bond and Dawes, that the phenomenon had been also seen by Dr. Galle at the Berlin Observatory in the year 1838; but its exact nature was not made out, and consequently, the circumstance did not receive any further attention. It would seem, indeed, that Hadley observed the faint ring as early as the year 1723. In the course of his observations of the planet in that year, he remarked that the dusky line which in 1722 he observed to accompany the inner edge of the ring across the disc, continued close to the same, though the breadth of the ellipse had considerably increased since that time ('Phil. Trans.,' 1723, No. 378). He asserts, moreover, in reference to the hypothesis of the belt being produced by the shadow of the ring upon the planet, that when he considered the situation of the sun, with respect to the ring and the planet, he found that the belt could not arise from such a cause.

From an examination of the recorded measures of the rings of the planet, extending from the time of Huyghens down to the present day, M. Otto Struve was induced to conclude that the rings are gradually approaching the body of the planet. Mr. Main, however, who recently subjected to a thorough discussion his own measures of the Saturnian system, has discovered no trace of the existence of such a movement.

The question with respect to the physical constitution of Saturn's rings, and the mechanical conditions which assure their stability, has naturally given rise to much speculation. Laplace, who investigated the question of stability, concluded that in order to prevent the rings from being precipitated on the body of the planet they must be irregular in their contour. Several succeeding astronomers and mathematicians have considered the same subject. The most complete investigation of it is due to Professor Clerk Maxwell; he concludes that the only system of rings which can exist mechanically is one composed of an indefinite number of unconnected particles, revolving round the planet with different velocities according to their respective distances. These particles may be arranged, in series of narrow rings, or they may move through each other irregularly. In the first case the destruction of the system will be very slow; in the second case it will be more rapid; but there may be a tendency towards an arrangement in narrow rings, which may retard the process.

We shall conclude this article with referring to an admirable delineation of Saturn and his rings by Mr. De la Rue, founded on his own observations with his 13-inch reflector. Several valuable measures of the Saturnian system by Mr. Main, Mr. De la Rue, Mr. Dawes, and other observers, will be found in the recent volumes of the Memoirs and Monthly Notices of the Royal Astronomical Society. In the 28th volume of the Memoirs the reader will find an elaborate investigation of the orbits of the Satellites (except those of Mimas and Hyperion) by Captain Jacob.

SATURNA'LIA, a festival celebrated by the Romans in honour of the god Saturnus. [KRONOS.] According to some traditions, it had been celebrated by the aborigines long before the building of the city, and was instituted by the fabulous king Janus, after the disappearance of Saturnus from the earth. Others said that it was instituted by the Pelasgians, or by the followers of Hercules, who had been left behind in Italy. (Macrob., 'Sat.,' i. 7.) A second set of traditions referred the institution of the Saturnalia to a much later period; one of them ascribed it to King Tullus Hostilius, who, after a successful war against the Albans and Sabines, was said to have founded the temple and established the festival of Saturnus at Rome. (Macrob., 'Sat.,' i. 8.) Another tradition, adopted by Livy (ii. 21) and Dionysius (vi., *ab init.*), which refers it to a still later time, ascribed the institution of the Saturnalia to the consuls A. Sempronius and M. Minucius (497 B.C.). The apparent incongruity of this and some other accounts may easily be removed: those who trace the Saturnalia to a period antecedent to the building of the city, can only mean that the worship of Saturnus was very ancient in Italy, while those who assign a later date to the institution must be understood to refer to the introduction of the worship into the city of Rome; and although festivals in honour of Saturnus may have been celebrated at his altar in the Roman Forum previous to 497 B.C., yet the regular and periodical celebration of the Saturnalia may not have been established before this time, when a temple was dedicated to the god in the clivus leading from the Forum to the Capitol. After this time the Saturnalia were celebrated regularly every year, on the 19th of December, the whole of which month was sacred to Saturnus; but after J. Cæsar had added two days to this month the celebration began on the 17th (Macrob., 'Sat.,' i. 10), and the people, being fond of such merry-makings, continued the festivities until the 19th, and even longer. Augustus at last sanctioned the celebration of the Saturnalia during three days, and Caligula and Claudius increased the number to five days. (Macrob., 'Sat.,' i. 10; Sueton., 'Calig.,' 17; Dion Cass., lix., p. 739.)

The Saturnalia was a harvest festival, and was held, as we have seen, at a time when all agricultural labours were over; and as at such a season every husbandman would naturally give himself and his servants a holiday, and offer his prayers to the god whose especial protection he solicited, so the Saturnalia were national festivals instituted with the same object. It was generally believed that during the golden age of the reign of Saturnus there were no slaves, and the Saturnalia were intended to restore that happy state of things for a short time, by giving to servants and slaves a complete holiday. They were on this occasion allowed to appear in the dress of free citizens (Dion Cass., lx., p. 779), were waited upon at their feasts by their masters, were free from every kind of service, and enjoyed the most perfect freedom of speech. Even criminals were sometimes restored to freedom, and then dedicated their chains to Saturnus. The whole season was one of universal rejoicing for all the people of Rome, and the city resounded with the shouts, "Io, Saturnalia! Io, bona Saturnalia!" Everybody ate and drank plentifully, and invited or visited his friends and relations. It was also customary for persons to make presents to one another on this occasion (Senec., 'Epist.,' 18; Sueton., 'Aug.,' 75), and clients presented their patrons with wax-candles. (Macrob., 'Sat.,' i. 7; Varro, 'De Ling. Lat.,' iv., p. 19, Bipont.) Children generally received little figures, which were called oscilla, or sigilla, from which the last day of the Saturnalia derived the name "sigillaria." During this festival all business, private as well as public, was suspended; no war was commenced, no battle was fought, and no punishment was inflicted on offenders. (Macrob., 'Sat.,' i. 10.) The persons who offered sacrifices to Saturn had their heads uncovered.

The Greek writers, when speaking of the Roman Saturnalia, generally call the feast "Kronia," as they considered the two festivals, as well as the deities in whose honour they were held, Saturnus and Kronos, as identical. (Comp. Buttmann, 'Mythologus,' ii., p. 52, &c.; Hartung, 'Die Religion der Römer,' ii., p. 124, &c.)

SATURNUS. [CHRONOS.]

SATYR (Satyrus, Σάτυρος) is the name by which the ancients designated a class of rustic deities, or Dionysii. Like the Panes and Fauni, they were a kind of intermediate beings between men and animals, and the features which they had in common with the latter were chiefly derived from goats. They were by some said to be the sons of Hermes and Ipthima. They seem originally to have been a sort of rustic or sylvan gods, who were worshipped in some parts of Peloponnesus. In the earlier works of ancient art they are represented with rather long and pointed ears, bald-headed, and with little protuberances like horns behind their ears. Sometimes their figure approached still nearer to the animal form, as they were represented with goats' feet and horns. During the best period of Grecian art the human form is entire, and the animal character is expressed by a little tail at the lower part of the back, and by a considerable degree of sensuality in the features and attitudes. They carry the thyrsus, shepherd's staff, or syrinx, wine-cups, &c., and are clad in the skins of animals, with wreaths of ivy, &c. Satyrs of a more graceful form are seen playing the flute, or, like Ampulus, as cup-bearers to Dionysos. Often, however, especially in later Greek and Græco-Roman art, they are of a lascivious character. Satyrs were the constant companions of Dionysos, and in the Dionysiac processions they always appear dancing, with cymbals or flutes in their hands. In the Greek drama the chorus at the Dionysia originally assumed the character of satellites of Dionysos, —that is, of satyrs,—and it is expressly stated that Arion not only invented the tragic dithyramb, but introduced satyrs, whence, according to some accounts, the name tragedy, or goats' song, arose. But the chorus of the Attic tragedy, in the course of time, gradually lost its satyric character, and a distinct satyric drama was developed, which is described by the ancients as a playful tragedy. The complete separation of this satyric drama from tragedy is ascribed to Pratinas of Phlius.

(Müller, *Archäolog. der Kunst*, § 385; H. C. A. Eichstädt, *De Dramate Græcorum Comico-Satyrico*, Lips., 1793; and, above all, Casaubon, *De Satyrica Græcorum Poesi et Romanorum Satira.*)

SAVANNA. [PLAINS.]

SAVINGS BANKS are institutions of modern invention, established in this country to encourage habits of prudence on the part of the poorer classes, who were previously without any places where they could safely and profitably deposit the small sums which they might be able to set aside from their earnings.

The origin of savings banks has been attributed to the Rev. Joseph Smith of Wendover, who, in the year 1799, circulated proposals, in conjunction with two of his parishioners, in which they offered to receive from any inhabitant of the parish any sum from twopence upwards every Sunday evening during the summer months, to keep an exact account of the money deposited, and to repay at Christmas to each individual the amount of his deposit, with the addition of one-third to the sum as a bounty upon his or her economy. The depositors were at liberty to demand and receive back the amount of their savings, without this bounty, at any time before Christmas that they might stand in need of their money.

The next institution of this kind that was established, of which we have any account, was founded at Tottenham in Middlesex, by Mrs. Priscilla Wakefield. This, which was called the Charitable Bank, bore a nearer resemblance to the savings banks of the present day than the Wendover plan. The Tottenham bank was opened in 1804. At first the accounts were kept by Mrs. Wakefield, who was assisted in other respects by six gentlemen acting as trustees, who undertook each to receive an equal part of the sums deposited, and to allow five per cent. interest on the same to such depositors of 20 shillings and upwards as should leave their money for at least a year in their hands. In proportion as the amount of the deposits increased, additional trustees were chosen, so as to diminish the loss, which might otherwise have been considerable, owing to the high rate of interest that was allowed. In 1808 a society was formed at Bath, managed by eight individuals, four of whom were ladies, who received the savings of domestic servants, and allowed interest upon the same at the rate of four per cent.

The Parish Bank Friendly Society of Ruthwell was formed in 1810 by the Rev Henry Duncan, who published an account of his institution with the hope of promoting similar establishments elsewhere. This was the first savings bank, regularly and minutely organised, which was brought before the public, and it is doubtless owing to the successful example thus set, that previous to 1817 there were seventy savings banks established in England, four in Wales, and four in Ireland.

In the year just mentioned legislative provisions were first made for the management of these institutions. Acts were passed (57 Geo. III. c. 105 and 130) for encouraging the establishments of banks for savings in Ireland and England respectively. Under these Acts, the trustees and managers, who were prohibited from receiving any personal profit or advantage from the institutions with which they should be connected, were required to enrol the rules of their institutions at the sessions. A fund was established in the office for the reduction of the national debt in London, entitled, "The Fund for the Banks for Savings," and to this fund the trustees were bound to transmit the amount of all deposits that might be made with them when the sum amounted to 50l. or more. For the amount so invested the trustees received a debenture, carrying interest at the rate of three-pence per centum per diem, or 4l. 11s. 3d. per centum per annum, payable half-yearly. The rate of interest then usually allowed to depositors was four per cent. In Ireland the depositors were restricted to the investment of 50l. in each year, and in England the same restriction was imposed, with a relaxation in favour of the first year of a person's depositing, when 100l. might be received. No further restriction was at this time thought necessary as to the amount invested, neither was the depositor prevented from investing simultaneously in as many different savings banks as he might think proper. This circumstance was found liable to abuse, and an Act was passed in 1824, which restricted the deposits to 50l. in the first year of the account being opened, and 30l. in each subsequent year, and when the whole should amount to 200l. exclusive of interest, no further interest was to be allowed. Subscribers to one savings bank were likewise not allowed to make deposits in any other.

In 1828 a further Act was passed, entitled "An Act to consolidate and amend the laws relating to Savings' Banks," and it is under the provisions of this Act (9 Geo. IV. c. 92) that all savings banks are at present conducted. It is provided herein, "that the rules of every savings bank shall be signed by two trustees, and submitted to a barrister appointed by the commissioners for the reduction of the national debt, for the purpose of ascertaining whether the same are in conformity to law, and that the said barrister shall give a certificate thereof, which, together with the rules signed by the trustees, shall be laid before the justices for the county, riding, division, or place at the general or quarter sessions; and it shall be lawful for such justices to reject and disapprove of any part or parts thereof, or to allow and confirm the said rules or such parts as shall be conformable to the act." The rules and regulations thus made and confirmed were to be deposited with the clerk of the peace for the county or division, and are then declared to be binding on the officers and the depositors of the institution. The money deposited in savings banks must be invested in the Bank of England, or of Ireland, in the names of the commissioners for the reduction of the national debt. The receipts given to the trustees of savings banks for money thus invested bore interest at the rate of 2½ *per cent. per diem*, or 3l. 16s. 0½d. per cent. per annum, while the interest paid to depositors was not in any case to exceed 2¼ *per cent per diem*, or 3l. 8s. 5¼d. per cent. per annum, the difference being retained by the trustees to defray the expenses of the bank. The trustees were not allowed to receive deposits from any individuals whose previous deposits have amounted to 150l., and when the balance due to any one depositor amounts with interest to 200l., no further interest is to be allowed. Friendly societies and charitable institutions were allowed to invest sums not exceeding 300l.

By another Act (3 William IV. c. 14) the industrious classes were encouraged to purchase annuities, to commence at any deferred period which the purchaser may choose, the purchase-money being paid either in one sum at the time of agreement, or by weekly, monthly, quarterly, or yearly instalments, as the purchaser may determine. The transactions under this act were to be carried on through the medium of savings banks, or by societies established for the purpose, and of which the rector or other minister of the parish, or a resident justice of the peace, shall be one of the trustees.

The 5 & 6 Wm. IV. c. 57, passed in September, 1835, extended the provisions of the 9 Geo. IV. c. 92, and of 3 Wm. IV. c. 14, to savings banks in Scotland, and enabled existing banks to conform to the said acts by preparing and depositing their rules pursuant to these acts.

Military or Regimental Savings Banks were established by warrant dated October 11, 1843.

On the 9th of August, 1844, the royal assent was given to an act (7 & 8 Vict. c. 83) entitled "An Act to amend the Laws relating to Savings Banks, and to the Purchase of Government Annuities through the medium of Savings Banks."

The first clause of this Act reduces, from and after the 20th of November, 1844, the interest of all moneys invested by the trustees of savings banks in the national funds, to the rate of 3l. 5s. per cent.; and s. 2 declares that the maximum of interest to be allowed to depositors shall not exceed the rate of 3l. 0s. 10d. per cent.

From the same date every depositor, on making his first deposit (s. 3), is to sign a declaration as provided by previous Acts, a copy of which is to be annexed to the deposit-book; and once in every year at least this book (s. 5) is to be produced at the institution for the purpose of examination.

Any actuary, cashier, or other person holding a situation at a savings bank (s. 4), receiving deposits and not paying over the same to the managers, is declared guilty of a misdemeanor; but no trustee or manager to be liable (s. 6) for any deficiency unless they have declared in writing their willingness to be so responsible, and this responsibility may be limited, except in cases of money actually and personally received by them.

When deposits are made in trust for another (s. 7), the sum is to be invested in the names of the trustees and the person on whose account the same is so invested; and repayment is not to be made without the receipt of both, or of their trustees, executors, or agents appointed by power of attorney.

Annuities under the 3 & 4 Wm. IV. c. 14 are not to exceed the sum of 30l. in the whole, but separate annuities to that amount may be granted to a husband and wife: but instead of the charges under the former Act, the charges are now (s. 9), for an annuity under 5l., the sum of 5s.; 5l. and under 10l., 10s.; 10l. and under 15l., 15s.; 15l. and under 20l., 20s.; 20l. and under 25l., 25s.; 25l. and not exceeding 30l., 30s.

Where deposits exclusive of interest do not exceed 50l. (s. 10), if a will or letters of administration are not produced within a month, the money may be paid to the widow, or the person entitled to the effects of the deceased; if a depositor be illegitimate and die intestate, the managers (s. 11), with the sanction of the barrister appointed to certify the rules, may pay the same to such persons as would be entitled to the same under the statute of distribution, if all the parties were legitimate; and where a married woman has made deposits it is lawful for the managers (s. 12) to repay such woman, unless the husband give notice to the contrary.

The time for issuing the half-yearly receipts for interest is extended (s. 13) to sixty days from and after the 20th of May and 20th of November; and the time for transmitting the annual statement is extended to nine weeks after the 20th of November in each year.

Any dispute between the depositors and the managers is to be settled (s. 14) by arbitration of the barrister appointed under the previous acts, whose award is to be exempt from stamp-duty; the barrister is empowered for this purpose (s. 15) to inspect the books of the institution, and to examine witnesses on oath or affirmation: false evidence to be punished as perjury.

Bonds given as security under previous acts (9 Geo. IV. c. 92, and 3 & 4 Wm. IV. c. 14) are to be deposited with the commissioners for the reduction of the national debt (s. 16), to be delivered up on the application of not less than two trustees and three managers when required to be cancelled. Every officer trusted with the receipt or custody of money (s. 17) is to give sufficient security; such security, when given by the treasurer, actuary, or any other officer receiving a salary, shall be by bond, which is exempted from stamp-duty.

The direction for depositing the rules of a savings bank with the clerk of the peace (s. 18) is repealed; but two written or printed copies of them are to be transmitted (s. 19) to the barrister for his certificate, who, on approval, is to return one copy to the institution, and transmit the other to the commissioners.

Payments to the relations of intestate depositors (s. 20) are to be made to the next of kin by the law of Scotland, in the case of deposits in that country.

The act is declared (s. 21) to extend to societies for purchasing annuities as well as to savings banks, and (s. 22) to Great Britain and Ireland, Berwick-upon-Tweed, Guernsey, Jersey, and Isle of Man.

The 11 & 12 Vict. c. 133, limits the liabilities of trustees in Ireland, except for money actually received by them and not paid over, to any sum specified by them in writing, not being less than 100l.

By the 16 & 17 Vict. c. 45, the amount of annuities granted is extended to 30l., but still not to be less than 4l., for one or two lives; and they may be granted to a husband and wife, though one may already have secured an annuity to the full amount.

By the 19 & 20 Vict. c. 41, the shipping-offices for saving are constituted branch savings banks, and the Board of Trade is empowered to make regulations for the investment and withdrawal of deposits.

Rules framed in agreement with the statutes have been issued by the commissioners for the reduction of the national debt. These rules provide, among other things, that no person being a trustee, treasurer, or manager of the society, shall derive any emolument, direct or indirect, from its funds; that the treasurer, and the paid officers of the society, shall give security for the faithful execution of their trust; that the age of the party, or nominee, upon whose life the annuity is contracted, must not be under fifteen years; that no one individual can possess, or be entitled to, an annuity, or annuities, amounting altogether to more than 30l., and that no annuity of less than 4l. can be contracted for; that minors may purchase annuities. The annuities are payable half-yearly, on the 5th of January and 5th of July, or on the 5th of April and 10th of October. If any person wishes to have an annuity payable quarterly, that object may be accomplished by purchasing one half payable in January and July, and the other half payable in April and October. Upon the death of the person on whose life the annuity depends, a sum equal to one fourth part of the annuity, beyond all unpaid arrears, will be payable to the person or persons entitled to such annuity, or to their executors or administrators, if claimed within two years. These annuities are not transferable, unless the purchaser becomes bankrupt or insolvent, when the annuity becomes the property of the creditors, and will be repurchased, at a fair valuation, by the commissioners for the reduction of the national debt. If the purchaser of an annuity should be unable to continue the payment of his instalments, he may at any time, on giving three months' notice, receive back the whole of the money he has paid, but without interest; or he may have an immediate or deferred annuity granted, according to the amount of money paid. If the purchaser of a deferred life annuity should die before the time arrives at which the annuity would have commenced, the whole of the money actually contributed, but not with interest, will be returned to his family without any deduction. If a person who has contracted for, or is entitled to, an annuity, becomes insane, or is otherwise rendered incapable of acting, such weekly sum will be paid to his friends for maintenance and medical attendance as the managers shall think reasonable, or any such other payments may be made as the urgency of the case may require, out of the sums standing in the name of the party. Any frauds that may be committed by means of mis-statements and false certificates will render void the annuity, and subject the parties offending to other and severe penalties. The rules of societies formed for carrying into effect the purposes of this Act must be signed by trustees, certified by the barrister appointed for the purpose, and enrolled with the clerk of the peace for the county or division in the manner already described with regard to the rules of savings banks.

Annuity tables, calculated under the direction of government, for every admissible period of age, and for every probable deferred term, may be had at the office of the commissioners for reducing the national debt, in the Old Jewry, London.

These measures appear to be well calculated for enabling the industrious classes to secure a small provision in the time of their youth and strength, for the days of their age and decline, and for inciting them, while yet unencumbered, to apply the surplus of their earnings to meet the wants of those who may become connected with or dependent on them in after-life.

The growth of these societies has been continuous from their establishment. We give below the number and amount in 1833, and add those of 1859; but it should be remembered that when the amount reaches 200*l.* it is usually transferred to the public funds, as interest is no longer paid. On the 20th of November, 1833, there were 385 savings banks in England holding balances belonging to 414,014 depositors, which amounted to 13,973,243*l.*, being on an average 34*l.* for each depositor. There were at the same time in Wales 23 savings banks, having balances amounting to 361,150*l.* belonging to 11,269 depositors, being an average of 32*l.* for each depositor; while in Ireland there were 76 savings banks, with funds amounting to 1,380,718*l.*, deposited by 49,872 persons, the average amount of whose deposits was 28*l.* The total for England, Wales, and Ireland was consequently 484 savings banks, with funds amounting to 15,715,111*l.*; the number of accounts open was 475,155, and the average amount of deposits was consequently 33*l.*

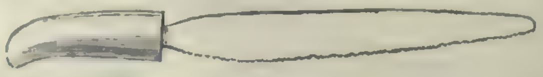
On November 20th, 1859, the total amount of deposits, including interest, in the United Kingdom, was 38,995,876*l.* The number of individual depositors was 1,479,723, of whom 213,473 were depositors of sums not exceeding 1*l.*, 294,739 not exceeding 5*l.*, 194,133 not exceeding 10*l.*, 140,092 not exceeding 15*l.*, 86,250 not exceeding 20*l.*, 148,575 not exceeding 30*l.*, 121,501 not exceeding 40*l.*, 58,032 not exceeding 50*l.*, 98,380 not exceeding 75*l.*, 45,580 not exceeding 100*l.*, 30,700 not exceeding 125*l.*, 18,134 not exceeding 150*l.*, 28,482 not exceeding 200*l.*, and 1652 above 200*l.* There were also 16,315 Charitable Institutions, with deposits amounting to 802,341*l.*, and 10,738 Friendly Societies, with deposits amounting to 1,731,095*l.* There were 580 Friendly Societies with direct accounts with the commissioners for the reduction of the national debt, their deposits amounting to 2,001,754*l.* The number of annuities granted through Savings Banks or Parochial Societies, from the commencement in 1854 to January 5, 1860, was 9707 immediate annuities, amounting to 196,112*l.*, for which 2,064,812*l.* had been paid, and of which 3046*l.* of the yearly amount of 59,432*l.* had fallen in; 160 deferred annuities on payment of one sum, to the amount of 2704*l.*, for which 30,979*l.* had been paid, and of which 26*l.* of the yearly amount of 478*l.* had fallen in; and 1875 deferred annuities for annual payments, to the amount of 37,486*l.*, for which 187,622*l.* had been paid; of these 1110 had fallen in, to the yearly amount of 21,390*l.*, and 44,037*l.* had been returned in consequence of death or default.

In November, 1858, the total amount of securities given by managers and trustees of savings banks had been only 67,070*l.*, and these almost entirely in Ireland.

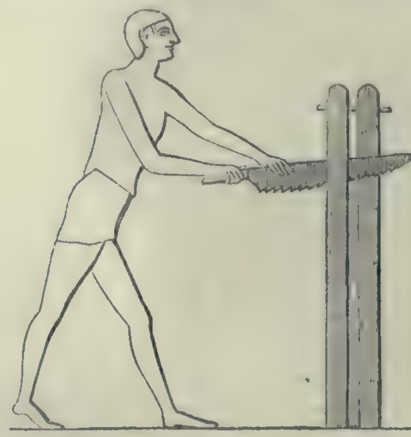
Much useful information as to the formation, management, and the means of ensuring the security of savings banks, will be found in 'A Practical Treatise on Savings Banks,' by Arthur Scratchley, M.D., 1860.

(*History of Savings Banks*, by J. Tidd Pratt; *The Law relating to the Purchase of Government Annuities through Savings Banks and Parochial Societies*, by the same author.)

SAW AND SAW-MILL. The division of wood by riving or splitting was probably the most ancient method of reducing it to pieces of convenient size and shape. If the grain of timber were straight, this plan would have the advantage of economy; but as it is not so in general, considerable waste is occasioned by riving when the pieces are required to be straight, much wood having to be removed with an adze in order to make it so. Hence the invention of saws.



Saws were used by the ancient Egyptians. The annexed cut represents a saw that was discovered, with several other carpenters' tools, in a private tomb at Thebes, and which is now preserved in the British Museum. The following cut, from Rosellini's work on Egyptian antiquities, represents a man using a similar saw; the piece of wood which he is cutting being held between two upright posts. In other representations the timber is bound with ropes to a single post; and in one, also copied by Rosellini, the workman is engaged in tightening the rope, having left the saw sticking in the cut. There is a curious picture among the remains discovered in Herculaneum, representing a carpenter's workshop, with two genii cutting a piece of wood with a frame-saw. On an altar preserved in the Capitoline Museum at Rome there is a representation of a bow-saw, exactly resembling in the frame and the twisted cord those used by modern carpenters.



Saws are of various forms and sizes. Those used by carpenters and other artificers in wood are the most numerous. Among these are the following:—The *cross-cut saw*, for dividing logs transversely, two persons being employed to pull the saw backwards and forwards, and the teeth being so formed as to cut equally in both directions. The *pit-saw*, with large teeth, and a transverse handle at each end. It is used for sawing logs into planks, the piece to be cut being laid over a saw-pit six or seven feet deep. One man stands on the log, and the other in the pit, and they pull the saw alternately up and down, the saw cutting in its descent only. The *frame-saw* is from five to seven feet long, stretched tightly in a frame of timber, the plane of the saw being at right angles with that of the frame. It is used in a similar manner to the pit-saw, but causes less waste, because the blade, being stretched, may be made much thinner. The *ripping-saw*, *half-ripper*, *hand-saw*, and *panel-saw* are saws for the use of one person, the blades tapering in width from the handle. They are of different lengths, the largest being about twenty-eight inches; and the teeth vary from one-third to one-eighth of an inch. *Tenon-saws*, *sash-saws*, *dovetail-saws*, &c., are very thin, of equal width throughout their whole length, and stiffened with stout pieces of iron or brass fixed on their back edges. These are used for many purposes for which a neat clean cut is required, but where it is not necessary for the whole width of the saw-blade to pass through the wood. *Compass* and *key-hole saws* taper from about an inch to an eighth of an inch in width, and are used for making curved cuts. Small *frame-saws* and *bow-saws*, in which very thin narrow blades are tightly stretched, are occasionally used for cutting both wood and metal. Saws are made for cutting bone, iron, brass, and many other hard substances; and there are several varieties used by the carpenter besides what have been enumerated; but it is unnecessary here to detail them.

The very commonest kind of saws are made of iron-plates, hammer-hardened, and planished upon an anvil, to give them some degree of stiffness and elasticity. The more useful saws are made either of shear or cast steel. The steel is cast in the form of a small slab, about an inch and a half thick. This slab is extended, by rolling, to the required degree of tenuity, and then cut, by shears, into pieces of suitable form and size. The edges are next perfected by filing, and holding the flat side of the plates against large grindstones, which process prepares them for the cutting of the teeth. This operation is usually performed by a die-cutter in a fly-press, the motion of the saw-plate being duly regulated, so that the teeth shall be uniform; the larger teeth being cut one at a time; and the smaller two, three, or more at a time, according to circumstances. The wire edges left on the teeth by the cutting-out press are removed by filing; after which the plates undergo the processes of hardening and tempering. They are heated to a cherry-red and dipped into a fatty composition. When sufficiently cooled therein to be handled, they are taken out, and are found to be extremely hard and brittle. They are passed backwards and forwards over a clear charcoal fire, so as to cause the unctuous matter to inflame, or *blaze off*, as it is termed, which reduces the saws to the required temper; and, whilst the saw-plates remain hot, any warping they may have acquired in the process is removed by smart blows from a hammer. The next operation is planishing by hammers, to make them more even and equally elastic: after which the saws are ground on large grindstones. As the grinding impairs the elasticity, they are submitted to a second hammering, and to heating over a coke fire until they attain a faint straw-colour. The marks of the hammer are removed by again passing the saws lightly over a grindstone; after which the final polish is given by a fine hard stone, a glazing-wheel covered with buff-leather and emery, or a wooden wheel, called the *hard-head*. Any defects acquired during these processes are removed by a few blows with a small polished hammer upon a post of hard wood. The saws are "cleaned off" by women, by rubbing fine emery over them lengthwise with a piece of cork-wood. The *setter* lays each alternate tooth over the edge of a small anvil, and strikes them so as to bend each uniformly into a slight deviation from the plane of the saw; and then, turning the saw-plate, sets the remaining teeth in like manner, but in the opposite direction. The degree of deviation from the plane of the saw depends upon the kind of wood to be cut; the softest wood requiring the widest or *rankest* set. Sometimes an instrument with a notched edge, called a *saw-wrest*, is used for setting the teeth. After being set, the saw is placed, between two plates of lead, in a vice, and the teeth are sharpened with a triangular file. The handles are then fixed on by nuts and screws, and the saws cleaned off, oiled, and packed in brown paper for sale.

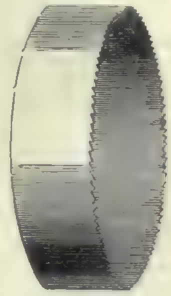
The teeth of carpenters' saws are so formed as to contain an angle of 60°, and they are made to incline more or less forward according to the intended use of the saw. Ripping saws have the front of the teeth perpendicular to a line ranging with their points. For very delicate operations saws are frequently made of watch-spring.

Saws for cutting stone are without teeth, although they are sometimes slightly notched upon the cutting edge. The saw-plate is tightly stretched on a kind of rectangular frame, of which it forms the lower side; and the frame, being suspended by ropes, is moved backwards and forwards by one or two men. Coarse sharp sand is used for cutting soft stones, and fine sand for those of harder quality. Sawing stone is a very slow and laborious operation. As in saw-mills for wood, any number of saws may be worked together, so adjusted as to cut a block of stone into slabs of any required thickness.

Saw Mill.—The machinery used for the purpose of converting wood from the log into squared lumber, or for subsequently cutting it up into plank, or veneer stuff, is known in the arts under the generic name of *saw mill*. It consists of a prime mover, setting in operation either a circular plate with serrated edges, vertical saw blades fixed rigidly in a frame, or a series of knife blades forming the segments of a large circular plate bearing a sharp cutting edge; and at the same time motion is communicated by the prime mover to a ratchet-wheel, which causes the frame to advance horizontally so as to keep the log of wood to be operated upon in actual contact with the edge of the cutting-tool. Rough logs and scantling stuff are cut by the circular saw; and deals, battens, and planks are dressed for the market by the same description of machinery. Thin boards (between 1¼ inch and ½ of an inch in thickness) are cut by the frame saw; and veneers, or thin slices of the harder and more precious woods, are cut by the plate saws with knife edges. As many as 100 veneers are at times cut out of planks only 1 inch in thickness.

The prime motors of saw mills may be either water-wheels, windmills, or steam-engines, and even in some cases horse-power is used. In mountainous districts, such as are usually covered with forests, water-wheels can generally be economically established, and they are rarely used for any other purpose than for squaring logs, or dressing plank stuff. Windmills are largely used in such countries as the Fens of East Anglia, and Holland, for both circular saws and frame saws; whilst the application of steam power to this purpose is the system almost universally adopted, in countries where fuel is cheap, for the ordinary kind of saw mills, and it is the only motive power ever employed for veneer cutting. Of late years, circular saws have been used for the purpose of cutting the ends of iron rails, and they also are invariably worked by steam power. The sizes of circular saws vary from 4½ to 60 inches in diameter; vertical saws are made of cast steel of Nos. 13, 14, and 15 gauge, and from 4 to 8 inches wide by from 3½ to 7 feet in length; veneering saws vary from 4 to 10 or 12 feet in diameter.

All the varieties of apparatus that have been described are for the purpose of making *straight* cuts; but it is sometimes desirable to produce *curved* forms by sawing, for which purpose there are several ingenious contrivances. Mr. Trotter has invented a concave circular saw, resembling a watch-glass in form, which is mounted in a bench like the common bench-saw, and to which the wood is directed by curved guides. Many useful forms are cut by a saw consisting of a cylinder of steel, toothed on the edge. Such saws are used for cutting circular pieces of wood to form the sheaves of blocks; and, when of larger dimensions, for cutting chair-backs, felloes of wheels, curved brush-handles, &c. For these purposes they are sometimes used as much as five feet in diameter. In another machine, an arrangement resembling the common reciprocating saw-mill is applied to curvilinear sawing, by causing the carriage on which the timber is supported to deviate from the straight course, and follow the curvatures of a model of the required form; while the saws, being attached to the frame by pivots, are capable of adapting their position to the curve.



Among the recent inventions in saw-machinery is a beautiful apparatus called the *band-saw*. It consists of a very long, narrow, and thin saw, made of highly tempered steel, and so flexible as to be wound round two rollers placed at such a distance apart as to keep the saw always on the stretch. When the rollers rotate, the saw is put in motion, and it thus becomes an endless saw, applicable to many purposes in the finer kinds of carpentry and joinery. Messrs. Powis and James's band-saw, patented in 1858, is an elegant example of this kind.

SAXON ARCHITECTURE. Until recently, all those old English churches of which the doors and windows had semicircular arches were usually termed Saxon. More careful study of our architectural antiquities showed that these were for the most part of Norman date; and it was then by many somewhat hastily assumed to be at least doubtful whether there were any buildings remaining of Saxon construction. That there are churches which were in part erected prior to the Norman Conquest there is now, however, no longer any dispute. Their number is indeed small, as might be expected; for the condition of the people, the disturbed state of the country, and the ravages of foreign invaders, would either prevent many churches, except of a comparatively rude character, being erected, or account for their destruction; and it will be readily perceived how churches which remained at the Conquest, would, one after another, with the progress of refinement be removed to make way for others of a costlier character, or more fashionable style of architecture; and that consequently, after the lapse of 800 years, but few fragments of such buildings should be extant.

Yet some vestiges, as we said, are left. Mr. Bloxam, who has paid particular attention to the subject, gives in the last edition of his 'Gothic Architecture' (1859, p. 90) a list of more than 90 churches (46 of which he has himself examined), which contain portions of presumed Saxon architecture. Mr. Rickman believed he had verified the existence of such remains in 120 churches.

Saxon architecture would be best described as the earliest form of Anglo-Romanesque. [ROMANESQUE ARCHITECTURE.] The earliest Anglo-Saxon architects made use of the materials of the Roman buildings, wherever they could obtain them, and imitated the Roman workmanship. In the brick walls and semicircular arches of the oldest Anglo-Saxon buildings, there are evident attempts to copy what is called the herring-bone work of the debased Roman architecture which prevailed in England. But the buildings were constructed by, or under the direction of, ecclesiastics who had acquired on the continent the current taste in ecclesiastical architecture; and who carried out their views as well as the skill of the workmen and the materials at their command permitted. For the more important buildings—and there are accounts in the chronicles of the erection of cathedrals and monastic edifices of considerable importance—foreign workmen were brought over. Accordingly, we find throughout the period a reference more or less direct to continental models, and, as might be expected from the connection of the court and the clergy, towards the latter part, a growing approximation to the Norman taste.

The style extends over a period of nearly four hundred years—from the latter part of the 7th to the middle of the 11th century. It is usually divided into two periods, the first extending to nearly the end of the 10th century, the second continuing to the Conquest. But the second period is that when the Norman influence prevailed, and when the style differed in little from the Norman but in its being less refined and artistic. [NORMAN ARCHITECTURE.] Here, therefore, it will be enough to indicate a few of the distinctive characteristics of the older variety.

No complete Anglo-Saxon church remains; but from those which are most perfect, as Brixworth in Northamptonshire, and from the references in Saxon records and the drawings in manuscripts, we see that the churches were rude, plain, and massive in appearance, and that whether cruciform, or with nave, side-aisles, and a tower at the west end, the chancel was usually apsidal. [APSIS.] Crypts appear to have been not uncommon in the larger churches, and a tolerably perfect one is still extant beneath the chancel of Repton church, Derbyshire. Towers were commonly very massive, divided into two or three stories by the rib-work described below; the surface being also divided by strips of similar rib-work, and having at the angles quoins of long-and-short work. The walls, where surmounted with a spire, or rather spire-roof, seem to have mostly had a gable-like termination; of this gable termination a good example remains in the tower of Sompting church, Sussex, though the roof-spire has been lowered. Of a more elaborate tower, Earl's Barton, Northamptonshire, is one of the most perfect existing examples. From their solidity of construction, the towers have proved the most lasting parts of Saxon churches.

The walls were usually built of coarse rag-stone, rubble, or flint, having as bonding at the angles oblong quoins set alternately upright and horizontal, so as to form what is called long-and-short work. Narrow ribs or strips composed of alternately long and short pieces of stone, projecting a few inches from the surface, are carried vertically up the face of the wall, and have been variously supposed to be rude imitations of pilasters or of timber-work. The piers were low and thick. The arches are either triangular, as at Brigstock, or, as is more common, semicircular. Windows are small; mostly, in fact, mere narrow openings. Sometimes, and the belfry-windows commonly, they consist of two semicircular-headed windows, divided by a thick and variously shaped baluster-shaft. Occasionally these double windows are enclosed within an arch or hood, formed of the pilaster rib-work above described: engravings of all these varieties will be found in Bloxam (ch. iii.), and other works on English Gothic architecture. The chancel arches are commonly small and quite plain, or have at most a moulded hood rudely worked on the face. Doorways have either semicircular or triangular arches: the former spring from plain projecting imposts, and are encircled with a hood of long-and-short rib-work which is usually carried down to the ground.

Mouldings are few and plain. In the later examples semi-cylindrical roll mouldings are not infrequent. In the older churches sculpture is seldom found; but later, rudely carved animals and flowers, knot-work, Greek crosses in relief, and other ornaments, are let into the walls. The imposts from which the arches spring are commonly mere rude massive blocks left square and plain, but they are sometimes moulded, and are occasionally rudely sculptured, as at Sompting, Sussex. Plain square string-courses are often met with; and inscriptions seem to have been not uncommon. The distinctive features of the style are, however, the long-and-short work of the quoins, the pilaster rib-work, the triangular arches, and the baluster-shafts of the belfry windows: the other particulars are not infrequent in early Norman work.

SAXON BLUE. [COLOURING MATTERS.]

SAXON LANGUAGE AND LITERATURE. The terms Saxon and Anglo-Saxon are popularly used to designate that dialect of our language which prevailed to the close of the 12th century. The use of these terms is, however, comparatively modern, and the men who spoke this dialect always called it the English. Several of our manuscript chronicles begin thus:—"Britain island is eight hundred miles long, and two hundred miles broad. And there are in the island five languages, *Ænglish*, and Brit-Welsh, and Scottish, and Pightish, and Book-Latin," &c. Still we may use these terms with some convenience, and (thus cautioned) without any danger of being misled. We proceed to point out the peculiarities which distinguish the Anglo-Saxon from the succeeding dialects of our language.

The Anglo-Saxon, like the Latin and the Greek, often distinguished the cases of its noun, and the conjugations, numbers, and persons of its verb, by a change in the vowel of the final syllable; in the dialect which succeeded, and which has been called the Old English, all these vowels were confounded, and in our modern dialect they have, for the most part, been lost. Thus the Anglo-Saxon *ath* has *athas* in the nominative and accusative plural, and *athes* in the genitive singular; the Old English *ath* has *athes* not only for its genitive singular, but also for its nominative and accusative plural; and in our modern English these three cases are all represented by the monosyllable *oaths*. Again, in the Anglo-Saxon, *athe* was the dative singular, and *atha* the genitive plural; in the Old English, *athe* represented both dative singular and genitive plural; and our present dialect, having lost the final vowel, had no means left of distinguishing these cases from the nominative *oath*. The third person singular of *lufian* was *lufath*, and the first, second, and third persons plural *lufiath*; in the Old English, *loveth* represented both numbers, and *lov'th* is the third person singular in the *spoken* language of the present day.

We say "spoken language," because our *grammarians* make *eth* the ending of the third person singular. But in Somersetshire, west of the Parret, where the southern dialect still lingers, they uniformly say *he lov'th, he read'th, he see'th, it rain'th*, &c. (Jennings, 'Obs. on the West. Dial.') We have very satisfactory evidence, that in the 16th and 17th centuries this dialect was general throughout the south of England, and we find numerous traces of its peculiarities in the literature of that period. Dolman wrote the following passage, in the 16th century:—

> "So, mid the vale, the greyhound seeing stert
> His fearful foe *pursu'th*, before she *flert'th*,
> And where she *turn'th*, he *turn'th* her there to beare,
> The one prey *prick'th*, the other safeties feare."
>
> *Mirr. for Mag.* Hastings.

Spenser has *melt'th* and *hat'th*, and Sackville *leap'th*. It is probable, that the inflexion used by the translators of the Bible, and which is found in other contemporary works, was merely an old form, taken from the language of books, and adopted chiefly with the view of raising the style. The same observation will apply to *est*, the inflexion of the second person singular, and to some other endings, which are still preserved entire in our grammars, though they have lost their vowel in the spoken language, for the last two centuries.

It is obvious, that either of the changes above noticed must have brought with it a new language. When, in the 12th century, the vowels of the final syllables were confounded, there was at the same time a confusion of case and number, of tense and person,—in short, of those grammatical forms to which language owes its precision and its clearness. A writer had to seek for new forms of expression before he could convey his meaning clearly. As he had lost the means of distinguishing several cases of his noun, he called in the prepositions to his aid, and to show more clearly the "regimen" of his sentence, was obliged to confine within very narrow limits the position of his verb,—thus abandoning all that freedom of transposition, which is almost as remarkable in the Anglo-Saxon as in the Greek and Latin. The confusion introduced into his conjugations and tenses, he sought to remedy by various devices, which have hitherto been very little investigated, and at last he had recourse to that general use of the auxiliary verbs, which is at present so marked a feature in the language. The new dialect which resulted from these changes kept its ground for nearly two centuries. It exhibits the most striking analogies with the contemporary dialects of Germany and the Netherlands, and the further changes which converted it into our modern English were rapidly working a like revolution in these sister-tongues, when the invention of printing doubled the influence of their written language, and thus preserved them from further corruption.

In tracing the causes which melted down the Anglo-Saxon into the Old-English, we have not once alluded to the influences supposed to have been exercised by the French language. The popular notions on this subject are, we believe, most erroneous. Had Harold been the conqueror at Hastings, the Anglo-Saxon must have perished, just as the Old-German perished in Germany, and the Old-Norse in Denmark. The victory of William merely hastened by a few years an event that was inevitable. The use of Norman-Romance as the court language of England rendered unfashionable a literature already too weak to stem those changes to which the language of a busy adventurous people is peculiarly liable; and thus far the Norman conquest may be considered as having assisted in the destruction of the Anglo-Saxon. But the vulgar notion, that it produced a mixed language, a jargon composed half of English and half of French, is wholly at variance with the manuscript literature of that period. The Ormulum, in which all the peculiar features of the Old-English are developed, and not a trace of the Anglo-Saxon can be found, is almost as free from *Gallicisms* as any of our manuscripts written before the Norman-French existed. The same may be said of most of the Old-English manuscripts of the 13th century, and it is not till we approach the latter half of the 14th century that we find those "cart-loads" of French words poured into the language, of which Skinner complains so loudly. We must reluctantly agree with this writer, in charging upon Chaucer much of the mischief resulting from these importations—not that he first introduced, but that his authority chiefly sanctioned them. The learned but pedantic writers of the Elizabethan era, and, at a later period, Johnson, followed his example.

Having noticed the changes which converted the Anglo-Saxon into the Old-English, we will now call the reader's attention to a subject of rather difficult inquiry—its local dialects. It is abundantly clear that the Romans looked upon all the Gothic races as forming but one people, and as speaking the same language; but a comparison of the Anglo-Saxon with the Moeso-Gothic, as well as the analogy of other languages, may convince us that even thus early there were dialects, and these dialects have now been acted upon by various influences for nearly 2000 years, till they have at last arranged themselves into four great families—the Northern, the English, the Low-Dutch, and the High-Dutch. Now we have ample proof that the *Seaxe* came from the south-western corner of the Cimbric Chersonesus, and that they were only separated by the Elbe from the Netherlands, or that alluvial country, where the Low-Dutch was spoken. We know also that the Engle came from the eastern coast, and that they were separated from the Danish islands merely by a narrow arm of the sea. We might then expect that in the counties colonised by the Engle we should find many peculiarities of the Northern languages, and in the counties colonised by the Sexe much that reminded us of the Netherlandish or Low-Dutch. We believe the Northern and Southern dialects of our island have been at all times distinguished by such peculiarities, but so few early records have come down to us written in the pure dialect of our northern counties, that it is only by comparing them in the second or Old-English stage of their progress that we can form any just notion of their distinguishing features. Perhaps these are best seen in the conjugation of the verb. The following table may show us how closely the inflexions which distinguish our northern dialect agree with those of a Swedish conjugation :—

	South Dialect.		*North Dialect.*		*Swedish.*	
Pres.,	Ich	hop-e	I	hop-es	jag	hopp-as
,,	thu	hop-est	thu	hop-es	du	hopp-as
,,	he	hop-eth	he	hop-es	han	hopp-as
,,	we	hop-eth	we	hop-es	vi	hopp-as
,,	ye	hop-eth	ye	hop-es	I	hopp-ens
,,	they	hop-eth	they	hop-es	de	hopp-as
Perf.,	thu	hoped-est	thu	hoped-es	du	hoppad-es
Imper.,		hop-eth ye		hop-es ye		
Infin.,	to	hop-en	to	hop-e	att	hopp-as

The inflexions in *s* are generally used in the Northern languages with a passive meaning; and there are some traces of their having been used in our Northern dialect for the same purpose.

Another peculiarity of our Northern dialect is the frequent use of the substantival ending *er* (in which it again resembles the languages of Northern Europe), as *wulfer*, a wolf; *hunker*, a haunch; *teamer*, a team; *heather*, heath; *fletcher*, a fletch, &c.

In this dialect we have also a less frequent use of the articles, conjunctions, and personal pronouns. This is one of its most striking features. Every person who has been in the North of England must have heard such phrases as "come out o' house," "gang into field," "put'n in poke," &c.

All these peculiarities of our Northern dialect may be traced to the Anglo-Saxon period; and there is little doubt that the most striking feature of the Southern dialect, namely, its preference of the vocal to the whisper letters, as *z* for *s*, and *v* for *f*, is equally ancient. It always prevailed in the Netherlandish dialects, and may be traced in the orthography of our Southern manuscripts to the beginning of the 13th century; but, as the Anglo-Saxons had neither a *v* nor a *z*, it is only by analogy we infer the existence of the corresponding sounds in their language. The argument however from analogy is so strong, that we may safely conclude either that the Anglo-Saxon *f*, *s*, were pronounced in our southern counties as *v*, *z*, or that, like the modern *s*, they represented both a whisper and a vocal sound; in other words, were pronounced sometimes as *f*, *s*, and sometimes as *v*, *z*.

It may possibly be asked, were not the forms here attributed to our Northern dialect introduced by the Danes? Are they not, in fact, the peculiar features of the "Dano-Saxon?" We will not affect to treat these questions as altogether without difficulty; but there are some considerations which may be laid concisely before the reader, and which, if they appear to him as forcible as they appear to us, may lead him to answer these questions in the negative.

In the first place, it must be remembered, that if no Dane had ever set foot on the island, the very results which *have* taken place might have been expected. It is also an argument of weight, that we find all the great features of our Northern dialect in places where there never was a Danish settlement, and vainly search for them, or at best only faintly trace them, in counties where we have historical evidence that the Northmen were numerous. But the strongest argument may be drawn from the pages of our Northern manuscripts. We have two of very ancient date—the Gloss of the Durham Bible, written by a priest named Aldred, and the Durham Ritual, published by the Surtees Society. The first of these was written, according to Wanley, in the age of Alfred, and the second has been assigned by its editor to the early part of the 9th century. If we can rely on the judgment of either of these antiquaries, the question seems to be answered; for there was no Danish settlement in the north of England till a later period; and we have the Northern conjugation and other peculiarities of the Northern dialect in every page of the Gloss, and in many parts of the Ritual. The name too of Aldred is thoroughly English; and we can hardly suppose that the monks of Durham would have permitted a rude and unlettered foreigner to interpolate their most precious manuscript—a volume which we know they regarded with even superstitious veneration. The language used by Aldred was probably a mixture of the written language of the day and the spoken dialect of his shire, such as might be used by a provincial writer of the present day, and such as was avowedly used by Gawin Douglas in the 15th century, and at a later period by Burns.

This mixture of the written and the spoken language in our manuscripts, and the total extinction in many counties of our local dialects, render it extremely difficult to point out the limits within which our two great dialects were spoken. Layamon, whose language seems clearly to belong to the Southern dialect, is described in all the histories of our poetry as a native of South Gloucestershire; but the localities mentioned in his poem belong to the north of Worcestershire; and he was, beyond doubt, an inhabitant of Areley-Regis near Stourport in that county. If he used the dialect of the neighbourhood (and this must be assumed till the contrary be shown), the Southern dialect must have prevailed over the whole of Worcestershire, and the men of that shire must have been Sexe in origin, and not, as hitherto supposed, a colony of Engle. Perhaps a line drawn from the north of Essex to the north of Worcestershire would pretty accurately define the portions of the island respectively colonised by the Engle and the Sexe.

The origin of the Midland dialect may admit of the following explanation. Neither natural obstacles nor political divisions ever separated the Northern and the Southern dialects. During the heptarchy, Gloucestershire and Oxfordshire belonged to Mercia, and not to the kindred race of the West-Sexe; and when the Danes held possession of the north of England, the shires of Warwick and Northampton, and generally that of Leicester also, were united in the closest ties with the Southern countries. This fellowship seems to have led, at a very early period, to the use of an intermediate dialect, which would naturally be encouraged by the vast numbers that flocked from all parts of the country to the universities. The 'Reve's Tale' affords us a specimen of the ridicule which attached to the forms of Northern speech, and we know that the speech of the Southern was treated with just as little ceremony in the north of England. (See 'Towneley Mysteries.') Hence we may understand the progress made by the intermediate dialect, and are prepared for the conclusion, to which we are led by an examination of our Old-English manuscripts, no less than by the express declaration of a contemporary philologist. Higden, who lived in the 14th century, ranges our provincial dialects under three heads, the Northern, the Midland, and the Southern; and this division seems to have been generally recognised by our antiquaries, for in our catalogues we find some manuscripts noticed as belonging to our Southern dialect, others as belonging to the Northern, while many of them, exhibiting the marked peculiarities of neither dialect, are passed over without remark.

The change which gradually produced the Midland dialect most probably first showed itself in the counties of Northampton, Warwick, and Leicester. It seems to have been brought about not so much by adopting the peculiarities of Southern speech, as by giving greater prominence to such parts of the native dialect as were common to the South. The Southern conjugations must at all times have been familiar, at least in dignified composition; but other conjugations were *popularly* used, and in the gradual disuse of these and other forms peculiar to the North the change consisted. We have many manuscripts written in the Midland counties, in which all trace of the Northern dialect seems to have been studiously avoided; yet in very many of them may be found some verbal inflexion in *es*, or some other popular form, quite sufficient to betray the writer.

The Northern dialect was still broadly spoken, within the last three centuries, in the counties of Lincoln, Rutland, Derby, and Stafford; but it has been gradually giving way before a language so much more widely understood, till it is now to be found only in scattered localities amid the mountains of the north of England, or in the lowlands of Scotland. The Southern dialect began to yield at a later period. It was certainly spoken at the beginning of the 17th century in all the counties round London. For specimens of the Middlesex dialect see Ben Jonson's 'Tale of a Tub;' 'Lear,' iv. 6, furnishes us with an example of the Kentish dialect; and nearly one half of 'Gammer Gurton's Needle' is written in the same dialect of Essex. Milton, when he issued forth

> "To breathe
> Among the pleasant villages and farms,"

must have heard a dialect around him in all essential particulars the same as the Somersetshire.

We will now take a rapid survey of the literature which belongs to the language whose history and peculiarities we have been endeavouring to trace. As in the case with the literature of most nations, we find that all its earlier specimens are metrical. We will therefore first call the reader's attention to our Anglo-Saxon poems; and to define more clearly the range of our present inquiry, we will briefly notice the properties which, at that early period, distinguished verse from prose.

An Anglo-Saxon verse is made up of two sections, which together may contain four, five, six, or even more accented syllables. These sections are bound together by the law of alliteration, or, in other words, each verse must have at least two accented syllables (one in each section) beginning with the same consonant or with vowels. Sometimes, and particularly in the longer verses, there are two such alliterative syllables in the first section, as in the verse

met | od for | thy *man* | e——*man* | cynne fram |

It is very incorrect to call this alliteration the "essence" or the "groundwork" of Anglo-Saxon verse. It is certainly an important part, but still a mere adjunct. The purposes it served were similar to those which are provided for by the final rhyme of our modern versification. The essence of Anglo-Saxon verse consisted in its system of rhythm. As the accents generally varied from four to six, it may be thought that the rhythm was too vague and loose, but in practice it is generally found sufficiently definite; and there are some of its rules which certainly give it a more scientific character than belongs to the system that has superseded it. For example, no sentence, nor any important member of a sentence, could end otherwise than at the close of a section. In our modern poets we often find a sentence ending in the midst of a section, or even immediately before the last syllable of the verse:—

> "His peers
> Have found | him guil | ty—of high-trea | son. Much—
> He spoke and learnedly for life," &c.;

but such a verse would not have been tolerated in an Anglo-Saxon poem. We may indeed find scores of such verses in the printed editions of these poems; but not one single example, and we speak advisedly, in any Anglo-Saxon manuscript.

The 'Gleeman's Song' is the oldest specimen extant of Anglo-Saxon literature. It is found in what is called the Exeter manuscript, one of the books left by Bishop Leofric to his cathedral, about the middle of the 11th century. Of the Gleeman himself we know nothing, save what can be learned from the poem; but from certain passages in it we may gather that he was born among the Mirgings, a tribe which dwelt on the marches that separated the Engle from the Swefe in the 4th century. In early youth he attended a Mirging princess named Ealhild to the court of Eormanric, the celebrated king of the East-Goten, and who figures so often in Roman history under the name of Ermenricus. ('Amm. Marc.' xxxi. 3, &c.) His professional skill appears to have gained him the favour of this monarch, and of the great lords who frequented the court, and whom he visited in their respective governments. He afterwards accompanied a Mirging prince into Italy, probably during the inroad of Alaric, A.D. 401; and as Gothic leaders were now rapidly gaining a footing in the empire, he seems to have seized the opportunity of wandering through its provinces. On his return, he must have been an eye-witness of the wars waged between Ætla (Attila) and the East-Goten; and as Ætla's accession dates only in 433, and Eormanric died in 375, he must have been more than seventy when he wrote the poem.

The 'Gleeman's Song,' like many other Anglo-Saxon poems, has a short preface in verse, which appears to be of almost equal antiquity with the poem.

Then follows a list of celebrated kings, from which the Gleeman selects for special notice Alexandreas, who appears to be Alexander of Macedon, and Wala, who is, no doubt, the Wallia that founded the kingdom of the Visigoths at Toulouse, A.D. 417. With the exception of Alexander, all of them appear to have been the Gleeman's contemporaries. After this enumeration he proceeds—

> "So I fared through many stranger lands,
> Through the wide earth; of good and evil
> There I tasted; from family parted,
> From kinsmen far, widely I did my suit—
> Therefore may I sing, and story tell,
> Relate fore the crowd, in mead-hall,
> How me the high-born with largess blest.
>
> I was with the Huns," &c.

We have then the names of nations and of countries visited by him, which appear to be strung together in the order best suited to the alliteration. There are also certain notices of the great people by whose bounty he had benefited, and the reader will not be surprised at the Gleeman seeing only a liberal patron in the same monarch (Eormanric) whom the author of the preface denounces as "a wrathful treachour." The whole concludes with a short eulogy on the dignity and privileges of his craft.

The great value of this poem lies chiefly in that string of names, which we have omitted as being so little interesting to the general reader. We do not stop to examine the question, whether any or how many of these notices have been interpolated during the five centuries which elapsed between the composition of the poem and the writing of the manuscript. Our knowledge of early Saxon history is so scanty that all such speculations must be hazardous. But we may observe, that the Scriptures had been translated into a Gothic dialect long before the Gleeman began his wanderings, and we know from Roman history that during the 4th century nearly one-half of the Gothic tribes were Christians. We need not therefore necessarily feel suspicion, when we read of the Assyrians and the Persians, the Jews and the Idumæans: they may have been as well known to the Gleeman as to the Saxon monk who transcribed the manuscript. The chief interest however attaches to the mention of the various Gothic, Slavish, and Finnish races. In tracing their history, the 'Gleeman's Song' is the great link which connects the knowledge gained from Latin sources with the information gleaned from the Middle-Age chronicle. In many instances it furnishes the only means of penetrating the mystery which surrounds these races. There are tribes, still to be found between the Wolga and the Vistula, which we can identify with others named by the Gleeman, and thereby prove to have had a political existence fourteen hundred years ago, of whom hardly another trustworthy memorial can be found, till within the last two or three centuries. The helps which it affords us in unravelling the web of Gothic fiction are also most valuable, and may, if rightly taken advantage of, save us from much of that speculation in which German scholars have indulged so largely.

There are two other poems, which must have been composed before the Engle left the Continent, the "Battle of Fins-burgh," and the 'Tale of Beowulf.' The first of these is a mere fragment, and appears to have belonged to one of those historical songs which Tacitus ('Germ.,' 2) represents as the only literature of the ancient Germans. The other is chiefly taken up with the relation of two of Beowulf's adventures: the first against a monster called the 'Grendel;' the second against a terrific "worm," or "earthdrake." The poem has come down to us in a modernised form, and the mixture of Christian and heathen notions is sometimes singularly curious. For the most part, the nature of the subject, and the marked change that takes place in the rhythm, enable us to lay our finger on the very line where the interpolation begins. The following is one of the attempts to reconcile the old superstitions and the new creed:—

> "The grim stranger was Grendel hight—
> Mighty pacer of the March; who held the moors,
> Fen and fastness—land of the Fifel-kin.
>
> The hapless man long had kept it,
> Sithen his Maker him had doomed.
> On Cain's kin the slaughter avenged
> The eternal Lord,—for that he Abel slew;
> For joy'd he in that feud, but him out-drave
> His Maker, for the sin, far from mankind.
> Thence evil births all proceeded,
> Ettyns, and Elves and Orknees;
> So too the Giants, that with God fought
> A long throw—for it he paid them meed!"

The Goths seem to have peopled every solitude with a race of monsters called the Fifel-kin. The sea, the moor, the fen, the marsh, or desert track which surrounded the territory of every Gothic tribe, were their dwelling-place. The battle, by which Offa settled the marches between the Engle and the Swede, was fought at Fifel-door (see 'Gleeman's Song'), and Alfred, when he brings his hero from Troy, launches him on Fifel-stream, that is, the monster-deep. Ettyns were long remembered in our popular superstitions:—

> "They say the king of Portugal cannot sit at his meat, but the giants and *ettyns* will come to snatch it from him."
>
> Beaum. and Fl. *Knight of the Burning Pestle.*

Elves still live in our poetry; and genuine Gothic giants (notwithstanding the worthy monk tried hard to convert them into rebel angels) still terrify or amuse the nursery. The Orknees are probably the same monsters as the Orks of the Italian romancers.

Some of the oldest pieces of poetry, written after the removal of the Engle to this country, and now extant, are the songs of Cædmon. The circumstances which first called forth the talents of this poet are related by Bede; and as he must have known many of Cædmon's contemporaries, his account may be looked upon as a simple narrative of facts. Cædmon, it appears, was neatherd to the monastery of Whitby, then under the government of its first abbess, the celebrated Hild. One day at supper, as the harp was passing from hand to hand, and it came to his turn to amuse the company, he stole from the room in one of those fits of diffidence which so often overtake the sensitive poet. As he slept in the neathouse, some one, he thought, encouraged him to sing, and the song he composed, and which was next day repeated to an admiring audience, established his reputation as a poet, and gained him the patronage of the abbess. He became a monk: was looked upon as one who had received the gift of song from above; and on his death his body was enshrined, and valued as one of their most precious relics by the monks of Whitby.

Only six of Cædmon's poems have reached us. The subject of the first is the Creation; that of the second, the Temptation and Fall, to which is added, rather inartificially, a narrative of the events recorded in Genesis, to the offering of Isaac; the third relates the Exodus; the fourth, the story of Daniel; and the Torments of the Damned, and Christ's Harrowing of Hell, followed by his Ascension and Glory, are the subjects of the other two. Bede tells us that he also wrote on our Lord's Incarnation and his Passion, as also on the Advent of the Holy Ghost, and the teaching of the Apostles. What remains is equal in length to about one half of the 'Paradise Lost.' [CÆDMON, in BIOG. DIV.]

We have called the 'Battle of Fins-burgh' an historical poem: another poem of the same class was written on the death of Byrthnoth, who bravely fell in resisting one of the Danish inroads, A.D. 993. Works, now lost, were written in the 11th century, by Leofric, Hereward's chaplain, on the warriors of our early history; and the songs commemorative of Hereward's exploits, which Ingulf tells us were in his day so popular, were probably written by the same hand. There can be little doubt also that many of the Old-English romances, as 'Horn,' 'Havelok,' 'Bevis of Southampton,' 'Guy of Warwick,' &c., are mere adaptations of Anglo-Saxon poems. Occasionally the subject was taken from foreign sources, of which the 'Tale of Judith,' probably written in the 10th century, affords a splendid example. The 'Tale of Apollonius of Tyre' is in prose, and a mere translation from the Latin.

There are other songs preserved in our chronicles, and closely allied to those last mentioned, but which are much shorter, and partake more of the lyrical character. Among them may be enumerated the Brunanburgh war-song, Edgar's coronation song, the two songs which commemorate the death of this monarch, and the elegy written on the death of the Confessor. The first and last of these are among the noblest specimens of Anglo-Saxon poetry.

A great deal of Anglo-Saxon verse was written during the 11th century. One of the writers seems to have been called Deor. His name occurs in a poem which exhibits many difficulties of construction, and perhaps some blunders of transcription; but it may be gathered that he was *scop* or minstrel to the Danish princes who succeeded Knut, and he appears to have lost his place at court when the Confessor mounted the throne of England. The name of Cynewulf has also been extracted from certain poems found in the Exeter and Vercelli manuscripts. It was hid in a kind of riddle, similar in character to our modern acrostic. He was probably the compiler of the two manuscripts, and may have been the author of much of the poetry which they contain.

But the noblest relic of this period is the Psalter published by the University of Oxford, from a manuscript preserved in the 'Bibliothèque du Roi.' In the first part, each psalm has an Anglo-Saxon translation in prose; and also a preface giving some account of its history, general scope, and tendency. The translation often paraphrases the Latin, so as to show more clearly its doctrinal or prophetical meaning: but from the 50th Psalm, the translation is metrical, and though generally literal, exhibits many cases of glaring misconstruction. The prefaces also disappear, and the whole seems to be the work of a man very slenderly provided even with the rudiments of learning. This deficiency, however, may now be considered as amply compensated for by the high character of the poetry. Some of the psalms are translated with a terseness and also an elegance, which place the translation far above any of our modern versions, and there is occasionally a Miltonic sweep of language, that has not often been surpassed even in the choicest specimens of our sacred poetry.

A note in the manuscript informs us that a priest named Wulfwin Cada "wrote it with his own hand" (manu suâ conscripsit). We think it extremely probable that Wulfwin copied from some manuscript the prose version as far as it went, and then drew on his own resources. There are numberless instances of transcribers altering and continuing the work they were copying. Most of our manuscript chronicles were transcripts up to a certain date, and were then continued as original compositions. The verb *conscripsit* shows it was a compilation; and if Wulfwin had before him a metrical translation, he would hardly, with that passion for stately language so common among his countrymen, have postponed it to the prose version. To Wulfwin Cada we think may fairly be ascribed both the faults and the merits of the metrical translation.

Among the most important prose works of our Saxon literature must be ranked those extraordinary compilations which are commonly called (as if they constituted but one work) the 'Saxon Chronicle.' The earliest copy of a Saxon Chronicle now extant is the Plegmund Manuscript, in the library of Corpus Christi College, Cambridge. It is written, as Wanley observes, in the same hand to the year 891, and in hands equally ancient to the year 924. After that date it seems to have been continued and interpolated by various transcribers, whose notices of Christ Church, Canterbury, leave little doubt that the volume was once the property of that cathedral. As Plegmund was consecrated archbishop in 890, and died in 923, it has been inferred that the original text was compiled by his order, and continued from time to time under his direction. The internal evidence favours this supposition. The notices which it contains respecting the operations of Alfred and his immediate predecessors could hardly have been furnished by any but those who were present at them, and were probably the substance of conversations which had passed between the prelate and the king.

The next copy, in point of time, is the Dunstan manuscript in the British Museum. This is also a Canterbury manuscript, and appears to have belonged to St. Austin's Abbey. It is written throughout in the same hand, and ends in the year 977. As Dunstan was then archbishop, and as the handwriting resembles that of other manuscripts ascribed to him, he has been named with some degree of confidence as the transcriber. However this may be, it must have been written by a man of scholarlike attainment. We have only to compare the passages which relate to the period after Plegmund's death, with the corresponding passages in the Christ Church manuscript, to see at once its superiority. This is particularly striking in the poetical portions. The noble ode on the battle of Brunanburgh would have remained for ever mutilated, and in parts unintelligible, but for the copy preserved in the Dunstan Chronicle.

Besides these two chronicles, we have a Worcester, an Abingdon, another Canterbury Chronicle, and a fourth, which appears to have been written at Peterborough. It has been inferred (chiefly for reasons connected with the handwriting) that these were compiled respectively in the years 1016, 1048, 1058, and 1125. We have also divers transcripts and collations made by Lambarde, Junius Josselyn, and other antiquaries of the 16th and 17th centuries, some of which were evidently taken from manuscript authorities no longer extant. Josselyn appears to have had in his possession a second Peterborough Chronicle; and Lambarde's transcript in Trinity College, Dublin, is thought to have been made from an ancient manuscript which perished in the fatal fire that destroyed so many of our Cottonian treasures. The Plegmund, the Dunstan, the Abingdon, and the ancient chronicle transcribed by Lambarde, all began with Cæsar's invasion. The Worcester, Peterborough, and latest Canterbury manuscripts begin with a description of Britain, extracted chiefly from Bede and Orosius.

The antiquaries of the 16th and 17th centuries seem to have assumed that the Anglo-Saxon monasteries kept a regular record of contemporary events; and there are certainly grounds for believing that registers of a certain kind were really kept by them. Bede's 'History' (iv. 14) has been referred to in proof of this. He tells us, that in the year 681 a boy, who was an inmate of Selsey Abbey, was seized with the plague, which was then desolating the country. As the poor lad was lying on his bed, he was accosted by two angel-visitants, who bade him tell the frightened monks that the plague would spread no farther, that it been stayed by the prayers of Oswald, of whose death that very day was the anniversary. "Let them," said Saint Peter, for no less a person is the speaker, "search in their books (in suis codicibus) in which are recorded the deaths of deceased persons (defunctorum depositio), and they will find that on this day he was taken," &c. The abbot, we are told, believed the boy's words, and straightway went and searched in his chronicle (in Annali suo), and found that on that very day King Oswald had been slain, &c. Here reference seems to be made to some public register of the convent; and this register, or the earlier manuscript it was copied from, seems to have furnished materials for the Peterborough Chronicle.

"An. 642. Now was Oswald, king of the Northhymbre, slain," &c., "upon the Maser-field, on the day called the nones of August," &c.

The mention of the day on which an event occurred, is rare in our chronicles; it is therefore probable that we have here the very passage which the worthy monk was sent in search of.

That there were also public (or perhaps we might say national) registers, in which were recorded the accessions, &c. of the kings, we also gather from the same venerable historian. We are told ('Hist.' iii. 4), such was the horror excited by the cruelties of the Welshman Ceadwalla, and the apostacy of the Northumbrian kings, that "it was resolved upon by all who had to reckon the chronology of the kings (regum tempora computantibus) that the memory of the faithless kings should be blotted out, and the year assigned to the reign of the the king next following," &c.; and he elsewhere adds, with studied phraseology, "unanimo omnium consensu firmatum est," 'Hist.,' iii. 9. In the Chronicles we have the entry:—

"An. 634.———And Oswald also took to the kingdom of the Northhymbre, and he reigned ix. winters. They assigned him the *ninth*, on account of the heathenism which they practised who reigned the one year between him and Eadwine."

Here we find, within a century after Ida landed at Bamborough, a register kept of the Northumbrian kings, and general interest excited as to the entries made in it. From details mentioned by Bede, and which could only have been supplied by written documents, it is clear that these historical notices reached to the times of paganism. They must have been originally written in English, and with Runes, those ancient characters which were only partially given up when Christianity introduced the literature of Rome, and which occasionally make their appearance in our manuscripts to the end of the 11th century. [RUNES.] A too literal translation of these venerable documents, no doubt, introduced the many *Anglicisms* to be found in the works of Bede, and even of the Welshmen Nennius and Asser. On this ground only can we account for the intrusion into the pages of scholars like the first and last of these writers, of such phrases as "victoriam sumpsere" (sige namon, An.-Sax.), "loco funeris dominati sunt" (ahton wælstowe geweald, An.-Sax.), &c.

With these materials at hand, we may readily understand the course followed in the compilation of our early chronicles. Who were the parties that continued and interpolated these chronicles, is a question very difficult to answer satisfactorily. Archbishop Elfric, Saint Wulfstan, Hugh White the monk of Peterborough, and others, have been named, with more or less of confidence, by different critics. For our own parts, we could never resist a feeling, almost amounting to conviction, that the character of William was the work of the venerable Wulfstan. It begins thus:—

"An. 1087.———If any wish to know what manner of man he was, or what state he held, or of how many lands he was lord, then will we of him write, as we him knew, we that have waited on him (the him onlocodon), and otherwhiles in his court have wonned," &c.

There were few English churchmen at the close of William's reign who could put forth this claim to the confidence of their reader, and still fewer that could have drawn William's character with the freedom and at the same time with the Christian feeling that distinguishes the whole of this noble composition. Wulfstan was at that time the only English bishop; and when, after describing the cruelty and sternness of the king, he adds the prayer, "may the Almighty God show to his soul mercy, and grant him of his sins forgiveness!" who does not feel that the moral qualities of the writer were as eminent as the opportunities enjoyed or the talents that improved them?

Among Anglo-Saxon prose writers, we must not forget the name of Alfred. His chief works are translations from the Latin, and of these the most remarkable are his versions of Bede, Orosius, and Boethius. Certain verses of the last-named author he has also paraphrased in verse. Among what may be termed his original works, are his accounts of the voyages of the two Northmen Wulfstan and Ohthere, which were inserted in Hakluyt's collection, and have been the subject of so much comment and criticism.

Archbishop Wulfstan, better known by the name of Lupus, was a voluminous writer of homilies. He was translated from Worcester to York in 1002, and must be carefully distinguished from the Saint Wulfstan already mentioned. A still more celebrated divine was Ælfric, the great champion who led the English church in its resistance to the Romish innovations of the 11th century. As might have been expected, his authority was appealed to, and with powerful effect, by the friends of the Reformation. One of Archbishop Parker's works is entitled 'A Testimony of Antiquity, showing the ancient Faith of the Church of England, &c., being a Sermon translated out of Latin into English by Ælfric, abbot of St. Alban's,' &c. It required all the exertions of the new theological school founded by Lanfranc and Anselm to keep under the principles so deeply sown by Ælfric.

We will close this notice of Saxon literature by observing that the influence it has exercised upon the modern literature of the country has been much underrated. Without maintaining, as some authors have done, that Milton diligently studied Cædmon, yet we do not fear to assert that some favourite images, and even certain terms of expression, may be traced through our literature, century after century, from the pages of the Saxon *scop* to those of Spenser and of Shakspere. The mistaken criticism which some of these have called forth might afford matter for instructive comment; and serve in some measure to teach us the value of a literature which has been so much neglected.

SAXONS is the name of a branch of the German nation. Their name is derived by some from that of the Saces on the Indus, by others from *sex*, a weapon, probably of the nature of a stone axe, and by others it is traced to the work *sassen*, that is 'settled,' in contradistinction from those German tribes who led a sort of nomadic life. The earliest writers who mention the Saxons describe them as neighbours of the Danes, south of the Cimbrian Chersonesus. ('Geograph. Ravennas,' iv. 17.) Ptolemæus also speaks of the islands of the Saxons, which were probably the modern islands of Eiderstedt, Nordstrand, Wicking Harde, and Böking Harde. Orosius (vii. 32) says that they inhabited a marshy country which was almost inaccessible to strangers. Towards the south-west they seem at first not to have extended beyond the Elbe. Tacitus, though he speaks of the Angli and Varini, who must have been close neighbours to the Saxons, does not mention them.

The similarity of their language to that of the Persians and ancient Indians affords reason for believing that the Saxons were of eastern origin; but how and when they came to occupy the north-western extremity of Germany, are questions which history cannot answer. Thus much only is certain, that at first they occupied a great part of the country between the Elbe and the Cimbrian Chersonesus; but when, during the migration of the barbarians, the neighbouring tribes changed their countries and migrated towards the south, the Saxons likewise began to extend in the same direction, and at last we find them occupying the country between the Elbe, the Rhine, the Lippe, and the German Ocean. This extensive tract of land is called by Anglo-Saxon writers Old Saxony, to distinguish it from New Saxony, or England.

In the 3rd century the Saxons often landed on the coasts of England and France, and ravaged the maritime districts; but about the middle of the 5th century (449) a large body of Saxons and Angles established permanent settlements in this island. The Angles, however, seem to have prevailed in numbers or influence, for it was they that gave the name to their new country, Angel-land, Anglia (England), though it was sometimes called Saxonia Transmarina. The name Anglo-Saxons, which comprises both Angles and Saxons [ANGLES and ENGLAND, in GEOG. DIV.] was invented by later historians for the sake of convenience. The history of the Saxons, who settled in England, and here, together with the Angles, became the origin of a new population, henceforth forms part of the history of England.

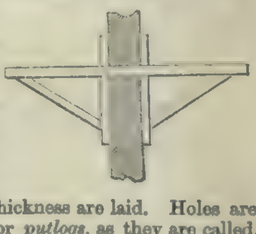
Those Saxons who remained in Germany conquered, about 530, conjointly with the Franks, the northern part of Thuringia as far as the little river Unstrut, but soon after gave up the eastern part of their conquest to a Slavonic tribe. The southernmost of the Saxons, about 550, became tributary to the Franks, to whom they paid an annual tribute of 500 cows. In proportion as the Saxons advanced towards the interior of Germany, and became better acquainted with the advantages of agriculture and the breeding of cattle, they gradually abandoned their former piratical mode of living, but remained nevertheless a spirited and warlike people.

Towards the close of the 7th century we find the Saxons divided into three great tribes, namely, the Ostfali on the western side of the Elbe, the Westfali in the country between the Rhine, Lippe, and Ems, and the Engeri in the centre, between the two former tribes, that is, on both banks of the Weser. Their hostile feeling towards the Franks was kindled into a war under Charles Martel, who conquered some Saxon districts on the northern banks of the Lippe, and made their inhabitants tributary. This, however, was only a prelude to the great and bloody wars which, with several interruptions, were carried on by Charlemagne from 772 till 803. During these wars many thousand Saxons fell in battle, and thousands were put to death because they refused to adopt Christianity. But they held out to the last, even after their chief Wittekind had submitted and become a Christian. The treaty of Selz on the Saale (803) at last terminated the war: the Saxons agreed to become Christians, and were put on a footing of equality with the Franks. Henceforth their history forms a part of that of the Carlovingian empire. To diffuse a knowledge of Christianity among them, and to establish the new religion more firmly, Charlemagne founded seven bishoprics, and from the places he appointed as the seats for these new ecclesiastical dignities, we may see the extent of country which they then occupied. The seats of the bishops were Osnabrück, Verden, Bremen, Paderborn, Minden, Hildesheim, and Münster.

SBIRRI, the name of a police force which existed in the Papal and other Italian states. They were not a military corps; they wore no uniform, and lived in their own houses; they received a small pay, and were furnished with arms. They were ready at any time of the day or night to rally at the summons of their captain, who was styled Bargello, for the purpose of tracing and arresting bad characters or suspected persons. Parties of them went their rounds in the towns at night. The Sbirri acted also as informers, and assumed various disguises for the purpose. They were placed under the orders of the respective governors of the towns and districts. This body of men fell at last into great disrepute: they were open to bribery, and often had a secret understanding with robbers and assassins. They were recruited from among bad characters, respited criminals, &c. In 1809 they were abolished in almost every part of Italy, and replaced by the Carabinieri, a regular military body, like the French gendarmes, who are found much more effective and trustworthy. Sbirri, however, are still employed in most of the Italian states, but generally under a materially improved institution.

SCABIES. [ITCH.]

SCAFFOLDING. A temporary wooden structure, by means of which the workmen employed in erecting the framework of a building are enabled to place the various materials in their definitive positions. Scaffoldings are either supported wholly, or in part, by the buildings to which they are attached; or they are made totally independent of those buildings, with points of support upon the ground. Sometimes the machinery for hoisting the building materials is placed upon the independent scaffoldings; at others, it is placed on the walls, or at the foot of the structure, or again, the materials may be carried up inclined roads formed in the scaffolding.



When scaffoldings are supported by the buildings they are designed to serve, they are usually formed by inserting cross-bearers in the walls (if the latter should be of a considerable thickness, and at some distance apart), which cross bearers project beyond the faces of the wall for a sufficient distance to allow the construction of a gangway for the workmen, and the extremities are strengthened by means of inclined struts. These cross-bearers are placed about 5 feet apart, horizontally; and in rows, vertically, about 6 feet apart; and upon them boards of 1¼ or 1½ inches in thickness are laid. Holes are left in the walls to receive the bearers, or *putlogs*, as they are called, and the feet of the struts are clipped by vertical ties, which clip also the putlogs, and thus form a complete frame acting on both sides of the wall; the whole of this framing is removed on the completion of the work, and the putlog-holes are filled in. When the walls are close together, the putlogs bear upon them without any struts, but the scaffolding in such cases rarely goes beyond the external face of the wall, so that the workmen are obliged to lay the materials "overhand." Chimney shafts are built in this manner, without framed scaffolding; many of the keeps of mediæval castles were built by means of framed projecting trusses; and in Viollet le Duc's 'Dictionnaire Raisonné de l'Architecture Française,' some curious illustrations of the manner in which the mediæval architects combined in the same scaffolding the functions of a working stage, and of an inclined road, will be found.

The ordinary scaffoldings used in the south of England, which are partially independent of the buildings, are composed of poles fixed in the ground at distances of about 9 feet from centre to centre; these poles are called the standards, and they are tied together by horizontal poles, or *ledgers*, at distances of about 6 feet vertically, as well as by raking braces. Upon the ledgers putlogs are laid at distances of about 4 or 5 feet, and with clear bearings, between the wall and the outer ledger, of from 3 feet 6 inches to 5 feet. The boards are laid upon the putlogs. Both the putlogs and boards are left loose, in order to allow materials to be hoisted without difficulty; but the standards, ledgers, and braces are firmly bound together by cords and wedges; nails or screws being, it is to be observed, rarely used in the construction of scaffolding. It is customary to strengthen some portions of the scaffolds thus formed, in order to provide for the reception of the hoisting machinery when stonework is used in conjunction with bricks; but of late years the scaffoldings of buildings in which stone is largely employed have been executed with framed baulk timber and constitute structures of great solidity. Detailed accounts of scaffolds of this description are to be found in the 'Transactions of the Institution of Civil Engineers,' in the 'Builder,' in the 'Nouvelles Annales de Construction,' in the 'Annales des Ponts et Chaussées,' &c., in Rondelet's 'Art de Batir,' Kraft's 'l'Art de la Charpente,' Perronnet's 'Nouvelle Architecture Hydraulique,' Fontana's 'Templum Vaticanum,' &c. Descriptions of scaffoldings which have been made to serve at the same time as centres, or supports for parts of the work of the permanent structure, are to be found in those works. In Foster's 'Bauzeitung' for 1854 there is a very good account of the suspended scaffolding used in the reconstruction of the Pont Neuf, to which it is desirable to call attention. See also Emy's 'Traité de la Charpenterie.'

The scaffoldings which are erected independently of the buildings, throughout, are in point of fact timber structures of a very elaborate description, and they have to resist not only the various actions produced by the movements of the materials and of the workmen, but also those produced by the wind, acting as the latter frequently does with a great leverage. It becomes essential, under these circumstances, to frame and brace the whole system with extreme care; and, should the scaffolding have to remain a long time in place, precautions must be taken to guard against any decay of the wood. This, of course, would be the most likely to commence in the portions of the scaffolding built into the ground, or in those directly exposed to the action of the rain; the scarf or tenon joints also are very likely in these structures, which always have a degree of flexibility, to give access to the atmospheric moisture, and thus to rot. It is only in buildings of the greatest importance, or of a very peculiar nature, that scaffoldings entirely independent of the walls are used; for their construction really requires the erection of a timber frame on each side of the wall, and is consequently a very costly operation. The scaffolds used for raising the obelisks of Luxor, and in the Piazza in front of St. Peter's at Rome, are amongst the most remarkable works of this kind yet executed. See Fontana and Emy.

SCAGLIOLA (from the Italian *scaglia*, a scale or shell) is an *incrustation* of artificial composition which is applied to columns, and produces the most perfect imitation of marble, from which it can hardly be distinguished either by the eye or the touch, as it takes an equally high polish and feels equally hard and cold. Scagliola has long been in use in Italy, where, according to Lanzi, it was invented by Guido Fassi of Carpi (1584-1649), and where it was afterwards much used for Florentine or inlay-work of the kind called *a commesso*. It was not introduced into this country before the latter half of the last century, and the earliest application of it was in the columns of the Pantheon in Oxford-street, London, built by James Wyatt. Since that time, it has been brought into more general use, the manufacture of it has been considerably improved, and it can be executed at a comparatively moderate cost. In fact, it has to a great extent superseded the use of coloured marbles for columns and other interior decorations. It is far less costly than any kind of variegated marble, though too expensive to be brought into ordinary use on every occasion, and it answers the purpose of the real material not only as regards appearance and effect, but durability also, since it will last quite as long as any other part of the interior of a building. There is besides the advantage attending it, that columns incrusted with scagliola may be made of wood and hollow, or else filled with a plaster core, and consequently do not require that support in the floor beneath them, which would be necessary if solid marble shafts were employed; or if required to support a bearing above them, the columns may be of brick or ordinary stone, and afterwards coated with scagliola. Nor is the use of this composition confined to columns and pilasters only, for it may be and indeed is applied to other ornamental purposes, for table-slabs, pedestal-stands, dados of rooms, borders of floors, &c.

The composition or cement itself is prepared from the purest gypsum, which is first broken into small pieces, and after being calcined is reduced to powder. It is then passed through a fine sieve, and mixed with Flanders glue, isinglass, &c. In this state it is mixed up with colouring matter of the hue required; and as it is generally employed for the imitation of variegated or veined marbles (all coloured ones being more or less so), as many different colours and shades of the same colour must be mixed up separately as there are in the kind of marble to be imitated. Thus prepared, the composition is applied to columns or other surface intended to receive it, and which has a rough coating of lime and hair. The different colours are laid on and mixed by the workman, and consequently much depends upon his skill and taste in regard to the exactness of the imitation or the beauty of the veining and streaking, which is done in the floating, as it is termed, or laying on the cement. The next operation is to prepare the surface for polishing, by rubbing it with pumice-stone and cleansing it with a wet sponge. The polish is then given by rubbing it again, first with tripoli and charcoal on a piece of fine linen, secondly with felt dipped in tripoli and oil, and lastly with oil alone. By this means a durable lustre is obtained equal to that of the finest and most highly polished marble. By means of scagliola, not only may the costliest and rarest stones, porphyry, verde antico, giallo antico, &c. be successfully imitated but any combination of colours may be produced; for instance, purple, or emerald green, streaked with gold, Siena veined with purple, or any other splendid caprice that fancy may dictate.

SCALD. [Burns and Scalds.]

SCALD, properly SKA'LLD, is an ancient Scandinavian word which signifies poet, as skálldmär or skálldkona signifies a poetess. The name is, therefore, sometimes applied to the Scandinavian poets in general; but it belonged more especially to that class of poets who celebrated in their songs the exploits of heroes. The Scalds were thus not merely poets, but also the historians of their nation. When Snorri Sturluson, the last and most celebrated of the Scalds (1178—1241), states that the Scalds indeed always praised their contemporary heroes most, but never attributed to them any fictitious deed, we must infer that the creative powers of these poets had no scope, at least as far as contemporaneous history was concerned. The form and mode of diction were thus the only parts in which they displayed their poetic powers; and how they availed themselves of this right is clear from the numerous specimens of Scaldic poetry still extant: they are full of the boldest and most extraordinary imagery, whence they are frequently very obscure and almost unintelligible.

Scaldic poetry is almost the only source from which we derive our knowledge of the ancient history of the north of Europe. A considerable portion of it goes back to the remotest antiquity, and contains only mythological legends; while another portion, in the form of poetry, contains historical accounts of contemporary events. Such poetical histories, very different from the rhymed chronicles of other nations, continued to be written down to the middle of the 13th century. The Scalds were generally in the service of a chief or king, whom they accompanied on his expeditions in the capacity of historiographers; and it was the pride of the chieftains to obtain such Scalds as possessed most ability and learning. Their services were richly rewarded by the heroes whose praise they sang.

We still possess a very long list of Scalds, among whom are persons of the highest rank, and even kings. The most distinguished, however, were those of Iceland, and it is to these that we are indebted for the collection of ancient poetical traditions known under the name of the Eddas. Those which are more historical are known as Sagas, though in many cases these are mythical or legendary, as in the saga of Ragnar Lodbrok, and the 'Heldensage von Völund' (our Wayland Smith). Between the time when the death-song of Ragnar Lodbrok was composed (about the end of the 8th century) and that of Snorri Sturluson [Biog. Div., where, by mistake, it is printed Sturulson], we have the names of upwards of two hundred Scalds, of whom the more eminent were, Egil Skallagrimson, who wrote in praise of Erik Blödaxe, king of Norway; Einar Skaloglam, on the deeds of Hakon Jarl; Eynind Skaldaspillar, one of the best of the race, whose 'Harkinamal' is also an eulogism on Hakon; Olaf Hvitaskald, said to be the author of a part of the prose 'Edda;' and Sturla Thordarson, the writer of the 'Rafnsmal;' but none of them possess the vigour and freshness of the earlier productions, though sufficiently curious as presenting pictures of the life and manners of the times. With the introduction of Christianity the poetic power was devoted to the celebration of saints and miracles, and the zeal of the priests succeeded not only in suppressing the inspiration of the poets, but in destroying the existing specimens, so that only in Iceland, where the priesthood was selected from the natives, and no foreign influence interfered with the old national literature, have any relics been preserved. Compare 'Fundgruben des Nordens,' by Legis; John Olafsen, 'Om Nordens gamle Digtekonst, Grundregler, Versarter, Sprog og Fóredrags mode,' Copenhagen, 1786; and the article Snorri Sturluson, in Biog. Div.

SCALE (Mathematics). A scale is any line drawn upon wood or other solid substance, and divided into parts, equal or unequal, the lengths of which may be taken off by the compasses, and transferred to paper, in aid of any geometrical construction. The manner in which the scale is divided depends of course upon the nature of the algebraical or trigonometrical expression the values of which are to be represented. When the subdivisions of a scale are equal, any of the methods noticed in Graduation may be employed to obtain them; but in other cases, and indeed in the preceding one, it is usual to form scales by copying from an original which is carefully made in the first instance.

The most simple of all scales is that in which the subdivisions are all equal, or, as it is called, a scale of equal parts. Such a scale is not only the most easily constructed, but may be considered as containing all other scales. For example, suppose it required to lay down very accurately an angle of 25°. It appears [Chord] that if the radius contain 500 equal parts, the chord of 25° contains 216 such parts and $\frac{4}{10}$ths of a part. With a good scale of equal parts, and 500 of them taken as a radius, the angle may be laid down, if required, much more correctly than by a common scale of chords. [Protractor.] The largest table of chords which is laid down on common scales has a radius of 3 inches, the 500th part of which, or about the 167th of an inch, is a very small length; and it is difficult to trust any scale so far without verification, except the scale of equal parts. In the latter species, one part may be tried against another, and any one may for himself very soon ascertain whether there be any perceptible error.

In all the most accurate species of drawing, it is better to rely on tables and a really good scale of equal parts than on any of the common scales, though the latter are generally very good, and will do abundantly well for ordinary purposes.

Long scales of equal parts are made with different subdivisions, ranging from the 30th part of an inch to the 50th. If the substance of the scale be ivory, an inch will very well bear division into 60 parts, but 50 is more convenient for decimal calculation. A common ivory scale, of a rectangular form, such as is usually found in cases of drawing instruments, if it have no trigonometrical lines laid down, usually contains the following scales of equal parts:—

1. The quarter of an inch divided into 10 equal parts, each of which is again subdivided into 10 equal parts by a Diagonal Scale. There are commonly two diagonal scales, one at each end of the scale of quarters, the one on the left dividing the 8th of an inch into 100 parts, and the one on the right the quarter. It will easily be seen that the 400th of an inch is a uselessly small quantity, even when the lines are drawn on ivory.

2. A set of scales in which the inch is severally divided into 30, 35, 40, 45, 50, and 60 equal parts: 10 of these parts make, in each case, one of the larger subdivisions of the scale, and one larger division is also divided into 12 equal parts; so that, when the larger division is made to represent a foot, feet and inches may be easily laid down.

3. A set of scales in which the larger divisions are $\frac{1}{2}$, $\frac{2}{5}$, $\frac{3}{4}$, $\frac{1}{3}$, $\frac{5}{8}$, $\frac{2}{3}$, $\frac{7}{8}$, and $\frac{3}{8}$ of an inch. The larger division is, as before, divided both into 10 and 12 parts.

When trigonometrical lines are laid down they are usually one or two scales of *chords*, the radius of each of which is found by its chord of 60 degrees; a scale of *rumbs*, which is nothing more than a scale of chords, the angular unit being, not a degree, but a point of the compass; a scale of sines, with one of secants sometimes added; a scale of tangents, and of semitangents, the latter being really the same scale as the former, but marked with double angles, semitangent being a technical term, not for the half of a tangent, but for the tangent of half an angle. We shall have something more to say of these lines under Sector. In Gunter's scale, as it is called, which is a scale of 2 feet in length, used in navigation, there are also scales of logarithms, of numbers, sines, tangents, &c., and also a scale of meridional parts [Rumb Line]; of these logarithmic scales we shall have to speak more particularly under Sliding Rule.

SCALE (Music). A great deal has been written on this subject, by mathematicians, by musicians, and by those who combine both characters; but, from various circumstances, hardly anything which is accessible to the young arithmetician wishing for something which may really be a help to him in his musical studies. The Greek scale [Music; Tetrachord], the only fruitless subject of inquiry out of all that is Greek, has exhausted the learning, science, and ingenuity of the best writers, with no result but this, that over-refinements of theory are found either to have hindered practical excellence, or to have arisen out of the want of it; most likely the latter. The learning however which it was necessary to apply to the explanation of the Greek writers, has made it usual to write on this subject more profoundly than on others of the same difficulty: it is our object in the present article to explain the musical scale, if possible, more simply, and in its simplest parts: leaving to the article Temperament such considerations as, arising out of the present article, are required by those who would understand the higher practical details of the subject.

The object of music being to please the ear, or the mind through the ear, there is no test of excellence nor criterion of fitness, in any one detail, except the opinion of the best judges. This seems to assume the question, for the best judges can only be described as those who best know what is good music. This circle cannot be avoided, either in speaking of music or any other of the fine arts; to taste we must appeal, but not to the taste of every one. All we have here to do with this is to remark, that the mathematical considerations employed in an article like the present are not to be considered as placing the musical scale upon a mathematical basis, but simply as showing that there is something like an explanation of those rules which derive their authority, not from the mathematical system which embodies them, but from the sanction of the majority of cultivated ears. Those things which are agreeable in practice are found to be in certain mathematical relations to one another which make the theory of the musical scale simple and interesting: but had it been otherwise, we should have left mathematical simplicity, and preferred a more pleasing complexity.

The sounds which are agreeable to the ear are found to be those which are the consequence of vibrations of equal duration following one another: and the pitch of the note depends on the rapidity of vibration only. [Acoustics.] The note called A, for instance, sounded at the same time on a harp, a flute, and a horn, presents three different characters, three different intensities, but only one species of vibration as to the time of lasting. If the first instrument communicate 430 vibrations in a second to the air, so does the second instrument, and also the third. With the difference of intensity or loudness, and with the difference of character, the twang of the harp, or the tone of the horn, we have nothing to do in considering the place of the note they sound in the scale; a cultivated ear discovers that they sound the same note, and a mathematician knows that they severally communicate to the air the same number of vibrations per second.

Let us then suppose a string to be mounted, and stretched at both ends, or, better still perhaps, suspended vertically [*] by one end, and bearing a weight at the other. If this string be then set in vibration by the finger or by the bow of a violin, a musical (that is, a pleasant) sound is produced, if the string be not too long, nor stretched by too small a weight. With the phenomena of vibration, as connected with the length, material, and stretching weight of the string, we have here nothing to do [Cord] except to remark,—1, That the ear observes that, material and tension remaining the same, the longer the string the lower the tone, and *vice versâ*. 2, That the mathematician knows that, *cæteris paribus*, the longer the string the fewer the number of vibrations in a given time, in inverse proportion to the length. Thus if a certain string, stretched by a certain weight, give 100 vibrations per second, a string of half the length, stretched by the same weight, will give 200 vibrations per second. If a vibration mean a double motion of the string, once backwards and once forwards, the effects begin to be musical soon after the string is short enough, or stretched enough, to give 30 vibrations per second.

The number of musical tones is, theoretically, infinite: that is, between any two tones as many different tones as we please can be interposed, no one of which is so high as the higher, nor so low as the lower. Highness and lowness of tone are terms which are purely relative, and refer to an effect upon the ear which does not admit of definition; common terms usually distinguish only extreme cases; thus, a tone disagreeably high is a squeak, and one disagreeably low is a growl. There is no absolute reason why we should call the former high and the latter low, rather than the contrary; and in fact the earlier Greeks (naming them after the parts of the throat in which they thought they were produced) called the squeaking sounds low, and the growling ones high. But while we endeavour to separate names from things, we must not forget that there is much which all men acknowledge of real connexion between the associations which accompany sounds and those derived from other sensible phenomena. For instance, it would be impossible to persuade any one, that if light and darkness were to be imitated by musical tones, the light ought to be represented by low notes, and the darkness by high notes: and a composer who should accompany words expressive of transition from darkness to light by a marked descent from the higher part of the scale to the lower, would be thought to mean irony or burlesque. No satisfactory explanation has ever come to our knowledge as to what associations are awakened by the lower notes of the scale which connect them with darkness; but that this connexion does exist is certain.

Taking such a string or monochord (*single string*) as above described, it is immediately found that any alteration of its length produces some alteration of the tone. If the change be very slight, a dull or unpractised ear may not readily perceive it; but let the alteration be carried a little further, and there can be no difficulty. Such tones, near to one another, when sounded together, have a disagreeable and jarring effect, accompanied by beats [Acoustics]; but when the second string has been considerably shortened (say that this is done gradually), the disagreeable effect ceases almost at once, and at the moment when the shortened string is to the longer one as five to six. Two sounds are then heard which *harmonise* together, and on their joint effect the ear dwells with pleasure until it becomes monotonous (this very common word is itself derived, as to its common signification here used, from the wearying effect of the same tone, or set of tones, long continued). In the mean while, and during the shortening of the string, the joint effect, though always disagreeable, is not equally so throughout; and there is one place in particular where the effect, though not agreeable to the beginner, is bearable for a little while, and highly agreeable to the practised ear, which knows that full compensation is at hand in what is called the resolution of the discord, or transition to a more harmonious combination in a manner which seems peculiarly natural. This intermediate and more tolerable phase of sound takes place when the shortened string is to the other as eight to nine. Moreover, it may be observed that this last combination, hardly bearable, is rendered perfectly so if the two tones, instead of being sounded together, are made to follow each other in succession, no matter how rapidly. In both these cases the student will observe that the proportion of the lengths of the strings is that of some small numbers, five to six, and eight to nine. And it is matter of experiment, that the more simple the proportions of the lengths of two strings (stretched by the same weight), the more useful the combination in music: it is usual to say, the more agreeable sounded by itself; but to this we cannot subscribe, as we believe that to most ears the more complicated combination of a *third* (presently to be described) is more agreeable than the less complicated one of a *fifth*.

Instead of speaking of the lengths of the strings, we may pass to the relative numbers of vibrations in a second, which are inversely as the lengths. Thus, two strings of ten and seven feet, stretched by the same weight, vibrate so that the one of ten feet makes seven vibrations while that of seven feet makes ten.

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[*] Woolhouse 'On Musical Intervals,' p. 64. The author repeated the experiments of Fischer [Acoustics] and found a monochord thus constructed better than the common one for the purpose. His result was that A (the second space of the treble clef) made 424 vibrations in one second.

We now proceed to consider the most simple combinations; and first, that of two to one. Let the second string be half the first, or make two vibrations while the first makes one: there is then not only a joint effect which is agreeable, but a peculiar sameness of the two notes, insomuch that two instruments made to play together in such manner that the notes of the second shall always be of twice as many vibrations as the simultaneous notes of the first, would be universally admitted to be playing the same air, with no more difference than of that sort which is heard when a man and a boy attempt to sing the same air together. This perfect sameness, for so it will be called, though the two instruments never sound the same tone together, admits of no explanation; for though the ratio of the simultaneous vibrations is the simplest possible (two to one), there is no perceptible reason why, because simple ratios generally give harmonious combinations, the most simple of all should produce an absolute feeling of identity of character in the two tones. To this circumstance however we owe the most material simplification of the musical scale; for let it be settled, for instance, what strings give agreeable notes between those of 20 and 10 feet long, and division by two will give all the strings which can be admitted between those of 10 and 5 feet; thus, if it be proper to admit a string of eight feet in the former set, one of four feet must also take its place in the latter.

Again, it is observed that the relative effect of two tones is always the same as those of other two, when the numbers of vibrations made in a given time in the first pair are *in the same proportion* as the corresponding numbers in the second pair. Thus, suppose that in a given time the numbers of vibrations made by four strings are 12, 18, 40, and 60. Then, since we see that

$$12 : 18 : : 40 : 60 \text{ or } \tfrac{18}{12} = \tfrac{60}{40}$$

we may say that, according as the first and second sounded together are pleasant or unpleasant, so are the third and fourth; also if an air beginning on the first string require an immediate transition to the second, then the same air begun on the third string will require an immediate transition to the fourth.

A *musical interval*, then, is given when the fraction which expresses the proportion of the vibrations of its two notes in a given time is given. By the interval $\frac{3}{2}$ we mean that of two notes, the higher of which makes three vibrations while the lower makes two. Thus, if 18, 23, and 30 be the numbers of vibrations made by three strings in the same time, and we wish to find a fourth note which is as much above the third as the second is above the first, we must not make a string of 35 vibrations in the same time (as the beginner might do), that is, not one of $30 + 23 - 18$, but one of $30 \times \frac{23}{18}$, or $38\frac{1}{3}$ vibrations in the same time.

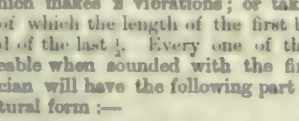
Let us now take a string, and call the note sounded by it C, and let the string of twice as many vibrations (or half its length) have the same name, with a difference (for the reason above given); call it C^1. Let us now seek for the simplest fractions which lie between 1 and 2. Take the numbers up to 6 (the ear does not so well agree with 7 and all higher prime numbers, why of course cannot be told, but simplicity must end somewhere, and, by the constitution of the ear, ratios in which 7 and higher primes occur are not agreeable), and form every fraction out of them which lies between 1 and 2; we have then—

$$\tfrac{3}{2},\ \tfrac{4}{3},\ \tfrac{5}{3},\ \tfrac{5}{4},\ (\tfrac{6}{4} = \tfrac{3}{2}),\ \tfrac{6}{5}$$

Put these down, with 1 and 2, in order of magnitude, and we have

$$1 \quad \tfrac{6}{5} \quad \tfrac{5}{4} \quad \tfrac{4}{3} \quad \tfrac{3}{2} \quad \tfrac{5}{3} \quad 2$$

Take such a set of strings that while the first makes one vibration the second makes $\frac{6}{5}$ of a vibration, the third $\frac{5}{4}$ of a vibration, and so on up to the last, which makes 2 vibrations; or take a set of strings equally stretched, of which the length of the first being 1, that of the second is $\frac{5}{6}$, &c., and of the last $\frac{1}{2}$. Every one of the notes thus produced will be agreeable when sounded with the first, and if the first sound C, the musician will have the following part of the scale before him in its most natural form:—



These intervals have the following names; why, will presently be seen,—

$\frac{6}{5}$ minor third.
$\frac{5}{4}$ major third.
$\frac{4}{3}$ fourth.
$\frac{3}{2}$ fifth.
$\frac{5}{3}$ major sixth.
2 octave or eighth.

We have not yet, however, got a sufficiently agreeable scale, and the reasons why the ear will not be contented with the preceding most simple concords, must be derived from observation, from which it appears—

1. That a frequent repetition of sounds very near to one another is not pleasing to the uncultivated ear. Now the interval from the minor to the major third is as follows: the first makes $\frac{6}{5}$ of a vibration while the second makes $\frac{5}{4}$, or the first makes 1 vibration while the second makes $\frac{5}{4} \times \frac{5}{6}$, or $\frac{25}{24}$. This is much too near to a unison for continual repetition.

2. That a frequent repetition of sounds too far from each other is not pleasing to the ear, after a little cultivation. If we look at the intervals from the fourth to the fifth, and from the fifth to the sixth, we find $\frac{9}{8}$ and $\frac{10}{9}$ for their representatives, while from the fundamental note to the minor third, and also from the sixth to the octave, the interval is $\frac{6}{5}$, much larger than the preceding intervals.

Both these defects, as must easily be seen arithmetically, and as the ear finds out for itself, may be remedied by inserting a note between C and E in place of E♭, which shall make a better division of the interval C E, and by placing an additional note between A and C^1. But how are we to choose these additional notes? If we cannot have any more very simple consonances with the fundamental note, we must take those tones which make the simplest consonances with other notes, and the more they make the better. We have already a repetition of some consonances; for instance,

Interval FC^1 is $2 \div \frac{4}{3} = \frac{3}{2}$, or a fifth.
Interval GC^1 is $2 \div \frac{3}{2} = \frac{4}{3}$, or a fourth.
Interval FA is $\frac{5}{3} \div \frac{4}{3} = \frac{5}{4}$, or a major third.

Now since $\frac{9}{8} \times \frac{4}{3} = \frac{3}{2}$, we see that a note $\frac{9}{8}$, or one which makes 9 vibrations while the fundamental note C makes 8, will be a fourth below G, and $\frac{9}{8}$ divides C and E well, the three notes 1, $\frac{9}{8}$, $\frac{5}{4}$, giving the intervals $\frac{9}{8}$, $\frac{10}{9}$, already found in another part of the scale. This note is D. Again, observe the interval from E to F, or $\frac{16}{15}$, and take a fifth above E, or $\frac{5}{4} \times \frac{3}{2}$ or $\frac{15}{8}$: this fraction falls between $\frac{5}{3}$ and 2, and looking at the intervals of $\frac{5}{3}$, $\frac{15}{8}$, and 2, we find $\frac{9}{8}$ and $\frac{16}{15}$, both of them intervals already found. This note $\frac{15}{8}$, or which makes 15 vibrations while the fundamental note makes 8, is B, and the usual scale of civilised nations, called the *diatonic* scale, is now complete in the following—

C	D	E	F	G	A	B	C^1
1	$\frac{9}{8}$	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{5}{3}$	$\frac{15}{8}$	2

This diatonic scale seems then to be the scale of the simplest concords of the fundamental note, with one alteration on account of the too great proximity of two concordant notes, and one interpolation on account of the too great distance of two others. If we examine all its intervals, we shall find both repetition and variety as follows (C D standing for the interval from C to D, &c.), some new appellations being added:

CD = FG = AB . . . = $\frac{9}{8}$ (major tone).
DE = GA . . . . = $\frac{10}{9}$ (minor tone, $\frac{80}{81}$ of major).
EF = BC^1 . . . . = $\frac{16}{15}$ (diatonic semitone).
CE = FA = GB . . . = $\frac{5}{4}$ (major third).
EG = AC^1 . . . . = $\frac{6}{5}$ (minor third).
DF . . . . . . = $\frac{32}{27}$ ($\frac{80}{81}$ of minor third).
CF = DG = EA = GC^1 . = $\frac{4}{3}$ (fourth).
FB . . . . . . = $\frac{45}{32}$ (flattened fifth).*
CG = EB = FC^1 . . = $\frac{3}{2}$ (fifth).
DA . . . . . . = $\frac{40}{27}$ ($\frac{80}{81}$ of fifth).
CA = DB . . . . = $\frac{5}{3}$ (sixth).
EC^1 . . . . . . = $\frac{8}{5}$ (minor sixth).
CB . . . . . = $\frac{15}{8}$ (seventh).*
DC^1 . . . . . . = $\frac{16}{9}$ (flat seventh).†
CC^1 . . . . . = $\frac{2}{1}$ (octave).

We observe here the consonances mentioned before, two inharmonious intervals, a new species of consonance (the flat seventh) standing as it were between the more perfect consonances and the others, and new varieties of a tone, of a minor third, and of a fifth, differing from those already described, and flatter by the interval $\frac{81}{80}$. This interval is called a *comma*, and though the ear can distinguish a difference between the tones of two strings, one of which vibrates 81 times while the other vibrates 80, yet the difference is so slight as to produce no prejudicial effect. With regard to the comparatively harmonious character of the flat seventh, observe that $\frac{16}{9}$ is very nearly equal to $\frac{7}{4}$, differing only by the interval $\frac{64}{63}$.

We have also the diatonic semitone, $\frac{16}{15}$, which is incorrectly named, since, if beginning with 1, we repeat the interval of a semitone twice, we have $\frac{16}{15} \times \frac{16}{15}$, or $\frac{256}{225}$, which is very near to $\frac{8}{7}$, sharper (that is, higher, as flatter means lower) than a major tone by the interval $\frac{89}{88}$ and than a minor tone by $\frac{43}{42}$, very nearly.

We shall presently resume the diatonic scale, but we now proceed to mention two varieties of it. It seems to have been offensive to the ears of rude nations to hear any semitones at all. If we deprive the diatonic scale of F and B, the notes which make semitones with their nearest neighbours, we have C, D, E, G, A, C, for all the sounds which remain in the octave. This unfinished scale, as we should call it, is the original scale of the Chinese, Avans, Hindus, and Eastern Islands, the northern nations of Europe, &c. It is the well-known scale of the old Scotch and Irish music; it is said to have been found in Wales and Cornwall, in various parts of Africa, and even in old Italian music. The Chinese, who never change, have preserved it in absolute perfection, though the modern form of most ancient airs in other countries has been relaxed. We copy the notes of a Chinese air given by Laborde :—

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* An inharmonious interval, when the notes are sounded together.

† Decidedly more harmonious than the seventh.

D C C G A G G C C A G E D C C G A G A A C E C A G G C C A G E C C E D A C

It will be observed that F and B never occur. An almost perfect specimen of this scale occurs in the Scotch air 'The Campbells are coming.' The effect of the scale may be tried by playing *ad libitum* on the black keys of a piano-forte.

The other scale which we have here to mention is that known by the name of the *minor* scale, the common diatonic scale being for distinction called *major*. It may easily be observed that the intervals of the minor third and minor sixth have a sad, or at least plaintive effect, as compared with the major third and major sixth. No explanation can be given of this: perhaps the effect of musical intervals is governed in some degree by associations derived from the human voice in speaking. All persons, except perhaps schoolboys reading what they do not understand nor care about, are constantly, whether they know it or not, varying the tone in which they speak, and making intervals which are very nearly musically correct: and the effect of sorrow, regret, fatigue, &c., is to make those intervals minor. Any person of a quick musical ear who will watch the method of saying the simple words "I cannot," pronounced as a determination of the will, and compare it with the same when it is an expression of regret for want of power, will almost always find such an interval as C F or C^1 G in the first, and C E♭ or C^1 A in the second; if this be so, it is not surprising that a scale in which minor intervals occupy conspicuous places which in the other scale are occupied by major intervals, should produce those associations which have been alluded to. This is a conjecture merely, for after all nature will take the liberty in art, as in science, of concealing her operations. But this much is certain, first, that the minor scale is more plaintive than the major, and secondly, that all musical composers are acquainted with the fact, from the African women who sung of Mungo Park, "Let us pity the white man, no mother has he to bring him milk, no wife to grind his corn," up to the composer of 'Der Freischütz,' with all the power of cultivation and the memory of centuries of art. The change from the minor to the major scale is perhaps the most effective of musical resources, certainly the most powerful of those which are easily understood by ears of the ordinary degree of cultivation. Take as an instance the music of the following words from Oberon :—

Oh-Araby,-blest-Ara-by, my own, my native-land,
Methought I-crossed-the dark-blue sea, and touched a-gain-thy strand;
And-there I saw my-father's house, &c.

The intervals with which the voice passes over the hyphens in the first two lines are minor, but in the third line a modulation is made into a major scale, and the composer has skilfully taken care to produce a strong result of the new scale in the first two syllables: the effect of the change is strikingly appropriate.

What is the minor scale? This question has been differently answered by different writers on the theory of music, who severally contend for one or another scale as *the true scale*. For ourselves, we are no believers in true and orthodox scales, or rather we hold every scale to have that character which has been used by good composers and approved by good hearers. It seems to have been thought that because there is one diatonic major scale, by universal consent, therefore there must be one lawful diatonic minor scale: just as well might it be said, that because the iambic trimeter is the one metre of Greek tragic dialogue, there must also be some one other metre, and that one only, in the choruses. Fortunately however the scholar knows, what the musician ought to know, that no one metre is dictated by any absolute law of taste, and teaches that the best tragedians must be the guide, because of the universal approval which has been conceded to their writings. Taking the same sort of guide, we find in the writings of musicians (the unknown authors of national airs, writers of very high authority, included) one major scale and several minor scales; a thing not more atrociously wrong in itself than the one metre of dialogue, and the variety of chorus metres, of the Greeks. And if, moreover, we take the mathematical theory of the scale, we shall find several with equal claims on the score of simplicity of consonances.

Return to the fundamental note C and its consonances, namely—

C	E♭	E	F	G	A	C^1
1	$\frac{6}{5}$	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{5}{3}$	2

Instead of throwing out E♭ as too near to E, let it be the latter which we reject; if we finish this with the D and B of the diatonic scale, we have what is called the *common* ascending minor scale, the commonness of which we cannot deny upon data, though it strikes us that others are as common, if not more so.

(1)	C	D	E♭	F	G	A	B	C^1
	1	$\frac{9}{8}$	$\frac{6}{5}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{5}{3}$	$\frac{15}{8}$	2

The ear will not very quickly acknowledge this as a minor scale in descent, and for the obvious reason that in going from C^1 to C there is no distinction between this scale and the major scale till we come to E♭; though in the ascent the minor interval occurs early. To remedy this, A and B are both lowered a semitone, or the A is made A♭, a fourth to E♭, and the B is made B♭, a fifth to E♭, which gives

(2)	C	D	E♭	F	G	A♭	B♭	C^1
	1	$\frac{9}{8}$	$\frac{6}{5}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{8}{5}$	$\frac{9}{5}$	2

and this scale reversed is called the common mode of descending the minor scale; but as we also find it used in ascending, we put it down as a second minor scale, both for ascent and descent, observing also that (1) may be, and is, used in descent. Again, suppose we retain the B of the original scale, and lower the A, we have then

(3)	C	D	E♭	F	G	A♭	B	C
	1	$\frac{9}{8}$	$\frac{6}{5}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{8}{5}$	$\frac{15}{8}$	2

a wild and pleasing scale, both in ascent and descent, and employed too, in spite of the wide interval between A♭ and B. Its harmonies, technically speaking, are easier and more natural than those of the common scale, and Schneider ('Elements of Harmony') makes it the principal minor scale, treating all others as incidental deviations: the English translator of Schneider contends for its absolute truth, and asks (justly enough) which scale a composer would take who was converting the air of 'Robin Adair' into the minor key (the original air having the notes G A B C D E) namely, G A B C D E♭, or G A♭ B C D E♭? There can be no doubt that the latter would be preferable, but we might add, that if the composer were required to make two variations in the minor key, he would probably choose scale (1) for his other case. The following minor scales are used, and are agreeable :—

(4)	C	D♭	E	F	G	A♭	B	C
	1	$\frac{16}{15}$	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{8}{5}$	$\frac{15}{8}$	2
(5)	C	D	E♭	F	G	A	B♭	C
	1	$\frac{9}{8}$	$\frac{6}{5}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{5}{3}$	$\frac{9}{5}$	2

Of all these minor keys, we prefer (3). For an instance of the use of it, take the first part of the air "Charlie is my darling," the notes of which run thus, C D E♭ F G C^1 G A♭ C^1 A♭ G C^1, C D E♭ F G C^1 D^1 E^1♭ C^1 D^1 B C^1. It is also the scale used in the first two lines of the air from Oberon, already noticed.

We now come to the extension of the diatonic scale by the interpolation of notes between all such notes as are far enough apart to bear it, which completes what is called the chromatic scale. There are various ways in which this can be done, and if notes were only occasionally interposed between those of the diatonic scale, it would be a subject of comparatively little importance how it was done. But we must now explain what is meant by different *keys* in music.

The note C having been fixed, and the diatonic scale on it, let an air be composed and written down, say 'Robin Adair.' The consecutive notes of the first part of this air, played in the key of C, that is, in the diatonic scale which has C for its fundamental note, are (we have nothing here to do with the time)

G A B C^1 D^1 E^1, G C^1 A C^1 B D^1 C

Let us now transpose this, as it is said, into the key of F, that is, show how it is to be played in a diatonic scale having the F of the preceding scale for its fundamental (or key) note. If all the intervals of the scale were equal, this would be done by playing as follows :—

C D E F G A, C F D F, E G F

Again, to remove this air into the key of A, or into the diatonic scale constructed on A, we should write (if the intervals were all equal),

E F G A B C^1, E A F A G B A

If we chose to confound the intervals of a major and minor tone, we should find the second of these (so it happens) correct, for the intervals of the original air are (m, minor tone; M, major tone; s, semitone) m M s M m (2 M + 2 m + s) (M + m + s) (M + s) (M + s) s (M + s) M, and those of the second are M m s M m (2 M + 2 m + s) (M + m + s) (m + s) (m + s) s (M + s) M, which are undistinguishable from each other, if M and m be supposed (as is the fact) too nearly equal to make it worth while to take account of their difference. But the third is s M m M s (2 M + 2 s + m) (M + m + s) (M + m) (M + m) m (m + M) M, which does not agree with either of the other two, nor can do so, except to an ear which cannot distinguish s from m or M. To see what intermediate notes will be wanted, we must construct a diatonic scale on each of the seven notes, which we shall now do, putting an equivalent to every note above C^1 or below C into the octave between C and C^1, by halving or doubling the fraction which expresses its vibrations. Moreover, we express the notes in the diatonic scale on D by D, D_{ii} D_{iii} D_{iv} D_v D_{vi} D_{vii} and D_{viii}; and so on. Also let ${}_{ii}D$ stand for an octave below D_{vii}, ${}_{iv}C$ stand for the note an octave below C_v, and so on, the rule being that ${}_{m}C$ and C_n are octaves when m and n together make *nine*. All this is well known, if anything of the scale be practically understood. What we have to do, for instance in forming the diatonic scale on F, is to take $\frac{4}{3}$, the representative of F in the diatonic scale of C, and multiply it successively by 1, $\frac{9}{8}$, $\frac{5}{4}$, &c. Our scales then are as follows, putting down under each note gained any note of the original diatonic scale, or any one of the scales previously formed, from which it differs insensibly little, removing each note an octave lower when necessary.

(D)	${}_{ii}D$	D	D_{ii}	D_{iii}	D_{iv}	D_v	D_{vi}	D_{vii}
	$\frac{135}{128}$	$\frac{9}{8}$	$\frac{81}{64}$	$\frac{45}{32}$	$\frac{3}{2}$	$\frac{27}{16}$	$\frac{15}{8}$	$\frac{135}{64}$
		D	E		G	A	B	
(E)	${}_{iii}E$	${}_{ii}E$	E	E_{ii}	E_{iii}	E_{iv}	E_v	E_{vi}
	$\frac{25}{24}$	$\frac{75}{64}$	$\frac{5}{4}$	$\frac{45}{32}$	$\frac{25}{16}$	$\frac{5}{3}$	$\frac{15}{8}$	$\frac{25}{12}$
	${}_{ii}D$		E	D_{iii}		A	B	D^{vii}
(F)	${}_{iv}F$	${}_{iii}F$	${}_{ii}F$	F	F_{ii}	F_{iii}	F_{iv}	F_v
	1	$\frac{10}{9}$	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{5}{3}$	$\frac{16}{9}$	2
	C	D	E	F	G	A		C^1
(G)	${}_{v}G$	${}_{iv}G$	${}_{iii}G$	${}_{ii}G$	G	G_{ii}	G_{iii}	G_{iv}
	1	$\frac{9}{8}$	$\frac{5}{4}$	$\frac{45}{32}$	$\frac{3}{2}$	$\frac{27}{16}$	$\frac{15}{8}$	2
	C	D	E	D_{iii}	G	A	B	C^1
(A)	${}_{vi}A$	${}_{v}A$	${}_{iv}A$	${}_{iii}A$	${}_{ii}A$	A	A_{ii}	A_{iii}
	$\frac{25}{24}$	$\frac{10}{9}$	$\frac{5}{4}$	$\frac{25}{18}$	$\frac{25}{16}$	$\frac{5}{3}$	$\frac{15}{8}$	$\frac{25}{12}$
	${}_{iii}E$	D	E	D_{iii}	E_{iii}	A	B	E_{vi}
(B)	${}_{vii}B$	${}_{vi}B$	${}_{v}B$	${}_{iv}B$	${}_{iii}B$	${}_{ii}B$	B	B_{ii}
	$\frac{135}{128}$	$\frac{75}{64}$	$\frac{5}{4}$	$\frac{45}{32}$	$\frac{25}{16}$	$\frac{225}{128}$	$\frac{15}{8}$	$\frac{135}{64}$
	${}_{ii}D$	${}_{ii}E$	E	D_{iii}	E_{iii}	F_{iv}	B	D_{vii}

In order therefore to make an instrument which shall play in perfect tune in every one of these diatonic scales, we must have it capable of sounding the following notes, those of the original diatonic scale, or very near to them, being in parentheses, and requisite notes of nearly equal sound being written under one another.

$$(1)\quad \begin{matrix}\frac{25}{24}\\ \frac{135}{128}\end{matrix}\quad \begin{pmatrix}\frac{9}{8}\\ \frac{10}{9}\end{pmatrix}\quad \frac{75}{64}\quad \begin{pmatrix}\frac{5}{4}\\ \frac{81}{64}\end{pmatrix}\quad \left(\frac{4}{3}\right)\quad \begin{matrix}\frac{45}{32}\\ \frac{25}{18}\end{matrix}\quad \left(\frac{3}{2}\right)\quad \frac{25}{16}\quad \begin{pmatrix}\frac{5}{3}\\ \frac{27}{16}\end{pmatrix}\quad \begin{matrix}\frac{225}{128}\\ \frac{16}{9}\end{matrix}\quad \left(\frac{15}{8}\right)\quad (2)$$

With this we might go on *ad infinitum*; for it might be required to construct new diatonic scales upon every one of these new notes, which would introduce more new notes, on which again new diatonic scales might be produced, and so on. But since the original scale consists only of major and minor tones (nearly equal) and diatonic semitones (nearly half-tones), the new notes will very nearly divide the whole tones into equal parts, a circumstance of which advantage will presently be taken. In the mean time we proceed to explain, so far as it can be done, the distinction musicians draw between *flats* and *sharps*. Unfortunately we are unable to make writers on this subject agree with each other, or with themselves, as to the meaning of these words in an *untempered* scale. The conventions under which the names sharp and flat are used come easily enough, and temperament avowedly makes small adjustments and accommodations between the several notes, which cause the sharpened A to be practically the same as the flattened B, and so on. But what the clear and admitted distinction of sharp and flat is previously to that adjustment, we wish we could evoke or provoke some musician to tell us. One word to those who write on the scale without much mathematical knowledge: get into a tempered scale as fast as you can, and keep there.

The nomenclature is regulated as follows. The notes A, B, C, D, E, F, G are preserved in every key; so that if any key contain A and a note between A and B, the latter is not called A♯—for then (A A♯) A would occur twice in the scale—but B♭, giving A B♭. Follow this rule in every one of the scales just given, and we shall find the following sets of notes in them severally:—

								Name of the Key.
C	D	E	F	G	A	B	C¹	(natural, . C)
D	E	F♯	G	A	B	C♯	D¹	(two sharps, . D)
E	F♯	G♯	A	B	C♯	D♯	E¹	(four sharps, . E)
F	G	A	B♭	C	D	E	F¹	(one flat, . F)
G	A	B	C	D	E	F♯	G¹	(one sharp, . G)
A	B	C♯	D	E	F♯	G♯	A¹	(three sharps, A)
B	C♯	D♯	E	F♯	G♯	A♯	B¹	(five sharps . B)

That is to say, a diatonic scale on D, for instance, only keeps D, E, G, A, B, or notes very near to them, of the diatonic scale, and requires the insertion of notes between F and G and C and D, which the avoidance of repetition of letters requires us to denote by F♯ and C♯, and not by G♭ or D♭. In the preceding keys then, we have five sharps mentioned (though really seven notes of the kind, two between C and D, two between F and G, one between each of D and E, G and A, A and B) and one flat (between A and B). Where are the other two sharps? If we construct diatonic scales upon F♯ and C♯ we shall find

F♯	G♯	A♯	B	C	D♯	E♯	F¹♯	(six sharps, . F♯)
C♯	D♯	E♯	F♯	G♯	A♯	B♯	C¹♯	(seven sharps, . C♯)

with not precisely the same notes as before, but very near to them, excepting two notes which are new: one between E and G (called E♯), and one note between B and C (called B♯). But on which of the values of F♯ and C♯ in the table are these scales to be constructed, and why? Again, as to the flats, if we construct diatonic scales on B♭, and on each new flat as it is successively introduced, we shall find that our nomenclature gives us new keys, as follows:—

B₁♭	C	D	E♭	F	G	A	B♭	(two flats, . B♭)
E♭	F	G	A♭	B♭	C¹	D¹	E¹♭	(three flats, . E♭)
A₁♭	B₁♭	C	D♭	E♭	F	G	A♭	(four flats, . A♭)
D♭	E♭	F	G♭	A♭	B♭	C¹	D¹♭	(five flats, . D♭)
G♭	A♭	B♭	C′♭	D¹♭	E¹♭	F¹	G¹♭	(six flats, . G♭)
C♭	D♭	E♭	F♭	G♭	A♭	B♭	C¹♭	(seven flats, . C♭)

But if we were actually to proceed to form this scale, beginning from B♭ ($\frac{16}{9}$) gained from the preceding process, we should find ourselves keeping very near the chromatic scale of sharps already obtained, so that the notes which appear in the preceding as remnants of the diatonic scale would really be close to the real notes. Let us see, for intance, what the F would be in the key of G♭:—

B♭, a fourth above F $=\frac{16}{9}$, E¹♭, a fourth above B♭ $=\frac{64}{27}$.
E♭ $=\frac{32}{27}$, A♭, a fourth above E♭ $=\frac{128}{81}$.
D¹♭, a fourth above A♭ $=\frac{512}{243}$, D♭ $=\frac{256}{243}$.
G♭, a fourth above D♭ $=\frac{1024}{729}$.
F¹ (so called), a seventh above G♭ $=\frac{1024}{729}\times\frac{15}{8}=\frac{640}{243}$.
F (so called) $=\frac{320}{243}$. F (really) $=\frac{4}{3}$.

Now from $\frac{320}{243}$ to $\frac{4}{3}$ the interval is only $\frac{81}{80}$, the comma, which we meet with so often elsewhere. But we should find different values for the same flat in the different keys above, just as we have found different values for the same sharp in the preceding. To show, however, in how confused a state the natural chromatic scale has been left, we copy three scales, the first from Wallis ('Phil. Trans.,' No. 242, 1698), the second from La Borde ('Essai sur la Musique ancienne et moderne,' vol. ii. p. 9, A.D. 1780), and the third from Montferrier ('Dict. des Math.,' vol. iii. p. 243, A.D. 1840). All these writers *omit the flats*, mentioning only the sharps:—

C	C♯	D	D♯	E	F	F♯	G	G♯	A	A♯	B
1	$\frac{18}{17}$	$\frac{9}{8}$	$\frac{45}{38}$	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{24}{17}$	$\frac{3}{2}$	$\frac{30}{19}$	$\frac{5}{3}$	$\frac{30}{17}$	$\frac{15}{8}$
1	$\frac{25}{24}$	$\frac{9}{8}$	$\frac{75}{64}$	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{45}{32}$	$\frac{3}{2}$	$\frac{25}{16}$	$\frac{5}{3}$	$\frac{225}{128}$	$\frac{15}{8}$
1	$\frac{16}{15}$	$\frac{9}{8}$	$\frac{6}{5}$	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{45}{32}$	$\frac{3}{2}$	$\frac{8}{5}$	$\frac{5}{3}$	$\frac{16}{9}$	$\frac{15}{8}$

It has been laid down by some writers that the definition of a sharp and flat is as follows: when it is necessary to take a note between, say A and B, that note is called A♯ when it is nearer to A, and B♭ when it is nearer to B. Let such be the definition; then the note which is exactly half way between C and D, being expressed by $\sqrt{(9:8)}$, is 1·0607, while $\frac{18}{17}$, $\frac{25}{24}$, and $\frac{16}{15}$ are severally 1·0588, 1·0417, and 1·0667. The two first only come under the denomination of C♯, according to this definition, while the third ought to be called D♭. In fact, this third scale is almost a scale with its semitones, collected from the minor keys which are found to please the ear, with a slight alteration and one addition. In (2) B♭ is made as a fourth to F, instead of a fifth to E♭ (giving $\frac{16}{9}$ in place of $\frac{9}{5}$, the interval of the two being only a comma); let $\frac{9}{5}$ be taken instead of $\frac{16}{9}$. Then between F and G insert G♭, a minor third to E♭ (giving $\frac{36}{25}$). Take the simplest sharps from the diatonic scales hereinbefore found, and, putting all the results together, we shall have the following, which, if a complete untempered ENHARMONIC scale is to be given, will, we believe, be as defensible as any. The sharps are all derived from the diatonic major scale, the flats from minor scales made by the usual minor intervals; the sharp of each note is lower than the flat of the following, though the former and the latter are not always in different halves of the interval:—

C	C♯	D♭	D	D♯	E♭	E	F	F♯	G♭	G	G♯	A♭	A	A♯	B♭	B	C
1	$\frac{25}{24}$	$\frac{16}{15}$	$\frac{9}{8}$	$\frac{75}{64}$	$\frac{6}{5}$	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{45}{32}$	$\frac{36}{25}$	$\frac{3}{2}$	$\frac{25}{16}$	$\frac{8}{5}$	$\frac{5}{3}$	$\frac{225}{128}$	$\frac{9}{5}$	$\frac{15}{8}$	2

The enharmonic intervals of this scale are as follows:—

C♯ D♭ = 1·024, D♯ E♭ = 1·024, F♯ G♭ = 1·024, G♯ A♭ = 1·024, A♯ B♭ = 1·024:

so that this enharmonic interval will be in every instance $\frac{128}{125}$, or 1·024. This circumstance was not looked for in the formation of the scale, and it is thus seen that if the sharps be derived from the major diatonic scales of the different notes in the fundamental diatonic scale, and the flats solely from the minor scales which have been judged admissible, the result is an enharmonic scale in which the enharmonic interval is everywhere the same, namely, the interval by which three major thirds fall short of an octave.

If an instrument could give all the above sounds, the same music played in different keys would have slightly different effects. We remember to have seen a statement of the supposed characters of the different keys, which would be useless here, on account of its not describing the scale which was supposed to be the basis. We might suppose beforehand that of two keys, the one in which some prominent consonances are a little flatter than in the other, would partake, in a slight degree more than the other, of the plaintive character which distinguishes the minor keys. But, in the first place, instruments in general, and particularly the piano-forte, on which the greater part of music first comes into existence, have not two notes interposed between each note of the diatonic scale, but one only, which must serve both to sharpen the lower, and flatten the higher. Next, the preceding scale would be found not very tolerable in some keys, particularly if laid down on an organ. Some TEMPERAMENT, that is, mutual accommodation of notes to each other, would be necessary, and though we defer to a separate article the account of the systems which prevail, or have been proposed, it will be desirable here to lay the mathematical foundation of the subject, which is easy enough to one who can use logarithms. The following table will be necessary, which we proceed to explain :—

1	00·00	51	68·07	101	79·90	151	86·86	201	91·81
2	12·00	52	68·40	102	80·07	152	86·98	202	91·90
3	19·02	53	68·73	103	80·24	153	87·09	203	91·99
4	24·00	54	69·06	104	80·40	154	87·20	204	92·07
5	27·86	55	69·38	105	80·57	155	87·31	205	92·15
6	31·02	56	69·69	106	80·73	156	87·42	206	92·24
7	33·69	57	70·00	107	80·90	157	87·54	207	92·32
8	36·00	58	70·30	108	81·06	158	87·65	208	92·40
9	38·04	59	70·59	109	81·22	159	87·75	209	92·49
10	39·86	60	70·88	110	81·38	160	87·86	210	92·57
11	41·51	61	71·17	111	81·53	161	87·97	211	92·65
12	43·02	62	71·45	112	81·69	162	88·08	212	92·73
13	44·40	63	71·73	113	81·84	163	88·18	213	92·82
14	45·69	64	72·00	114	82·00	164	88·29	214	92·90
15	46·88	65	72·27	115	82·16	165	88·40	215	92·98
16	48·00	66	72·53	116	82·30	166	88·50	216	93·06
17	49·05	67	72·79	117	82·44	167	88·60	217	93·14
18	50·04	68	73·05	118	82·59	168	88·70	218	93·22
19	50·98	69	73·30	119	82·74	169	88·80	219	93·29
20	51·86	70	73·55	120	82·88	170	88·91	220	93·38
21	52·71	71	73·80	121	83·02	171	89·02	221	93·45
22	53·51	72	74 04	122	83·17	172	89·12	222	93·53
23	54·28	73	74·27	123	83·31	173	89·22	223	93·61
24	55·02	74	74·51	124	83·45	174	89·32	224	93·69
25	55·73	75	74·74	125	83·59	175	89·41	225	93·76
26	56·40	76	74·98	126	83·73	176	89·51	226	93·84
27	57·06	77	75·20	127	83·86	177	89·61	227	93·92
28	57·69	78	75·42	128	84·00	178	89·71	228	94·00
29	58·30	79	75·65	129	84·14	179	89·81	229	94·07
30	58·88	80	75·86	130	84·27	180	89·90	230	94·15
31	59·45	81	76·08	131	84·40	181	90·00	231	94·22
32	60·00	82	76·29	132	84·53	182	90·09	232	94·30
33	60·53	83	76·50	133	84·67	183	90·19	233	94·37
34	61·05	84	76·71	134	84·79	184	90·28	234	94·44
35	61·55	85	76·91	135	84·92	185	90·37	235	94·52
36	62·04	86	77·12	136	85·05	186	90·47	236	94·59
37	62·51	87	77·32	137	85·18	187	90·56	237	94·67
38	62·98	88	77·51	138	85·30	188	90·66	238	94·74
39	63·42	89	77·71	139	85·43	189	90·75	239	94·81
40	63·86	90	77·90	140	85·55	190	90·84	240	94·88
41	64·29	91	78·09	141	85·68	191	90·93	241	94·95
42	64·71	92	78·28	142	85·80	192	91·02	242	95·02
43	65·12	93	78·47	143	85·92	193	91·11	243	95·10
44	65·51	94	78·66	144	86·04	194	91·20	244	95·17
45	65·90	95	78·84	145	86·16	195	91·29	245	95·24
46	66·28	96	79·02	146	86·28	196	91·38	246	95·31
47	66·66	97	79·20	147	86·40	197	91·47	247	95·38
48	67·02	98	79·38	148	86·51	198	91·55	248	95·45
49	67·38	99	79·55	149	86·63	199	91·64	249	95·52
50	67·73	100	79·73	150	86·74	200	91·73	250	95·59

Since all intervals are found by *multiplication* and *division*, it is obvious that if for intervals we substitute the logarithms of intervals, we form logarithms of new intervals by *addition* and *subtraction*. Hitherto, we express a note which makes a vibrations while the fundamental note makes b vibrations, by $\frac{a}{b}$; let us now express it by log a − log b, the logarithm of the preceding. It only remains to see what system of logarithms it will be most convenient to take. Having made the octave, or the interval from 1 to 2, consist of twelve semitones (not equal indeed, but nearly so), let us take a new scale, to which all others shall be referred, and which divides the octave into 12 *equal* semitones. This is a tempered scale, on the (theoretically) simplest system of temperament, and it is agreeable enough to the ear in practice. Let 1 be made the logarithm of the interval of any one of these mean semitones, then 12 is the logarithm of the interval of an octave, or we must choose that system of logarithms in which log 2 = 12. The preceding is such a table; to the mathematician it would be described as a system the base of which is $\sqrt[12]{2}$. But to the musician it may be described as follows: it shows the number of mean semitones contained in every HARMONIC of the fundamental note, from the first to the 250th inclusive. Thus, opposite to 21 we see written 52·71, which means that the 21st part of a string sounds a note which is 52 mean semitones and ·71 or $\frac{71}{100}$ of a mean semitone above the fundamental note of the string; or that there are 52·71 mean semitones of interval between two notes, one of which vibrates in a second 21 times as often as the other. This interval ·71 of a mean semitone is one which, repeated a hundred times, gives 71 mean semitones. All the numbers of the table must be understood to be approximate, within the hundredth of a semitone or thereabouts; which is more than exact enough for practical purposes. The following rule is all that is necessary :—If a note make $\frac{a}{b}$ vibrations while the fundamental note makes 1, then that note is log a − log b mean semitones above, or log b − log a mean semitones below, the fundamental note, according as a is greater than b, or b greater than a.

Example 1. What is the value of a comma in mean semitones? Log 81 − log 80 is 76·08 − 75·86 = ·22, and the answer is, that the comma is 22-hundredths, or something less than a quarter, of a mean semitone. Raising a note by a comma four times successively would not raise it quite a semitone.

Example 2. What is the enharmonic interval above obtained, in mean semitones? Log 128 − log 125 = 84·00 − 83·59 = ·41, or about four-tenths of a mean semitone. This shows that an untempered enharmonic scale, such as that proposed, if bearable when the sharps and flats are only incidental deviations, would never do for any other key except the natural one.

The following is the complete basis above given, of the enharmonic scale, with all the intervals, measured from the fundamental note, expressed in mean semitones; it shows how much alteration a system of mean temperament would require: it being remembered that although some few instruments have been made which give more than twelve different notes in the octave, this is so unusual a circumstance that it is not worth while to dwell upon it :—

							·41
C	1	00·00	·71	G♭	$\frac{64}{45}$	6·31	·71
C♯	$\frac{25}{24}$	00·71	·41	G	$\frac{3}{2}$	7·02	·71
D♭	$\frac{16}{15}$	1·12	·92	G♯	$\frac{25}{16}$	7·73	·41
D	$\frac{9}{8}$	2·04	·70	A♭	$\frac{8}{5}$	8·14	·70
D♯	$\frac{75}{64}$	2·74	·42	A	$\frac{5}{3}$	8·84	·92
E♭	$\frac{6}{5}$	3·16	·70	A♯	$\frac{225}{128}$	9·76	·42
E	$\frac{5}{4}$	3·86	1·12	B♭	$\frac{9}{5}$	10·18	·70
F	$\frac{4}{3}$	4·98	·92	B	$\frac{15}{8}$	10·88	1·12
F♯	$\frac{45}{32}$	5·90		C	2	12·00	

The first column gives the name of the note; the second, the ratio of its number of vibrations per second to those of the fundamental note; the third, the interval from the fundamental note in mean semitones; the fourth, the interval between each consecutive pair of notes. The small variations observable in the last column arise from imperfection of the table (every table must be imperfect in its last figures); and we see four intervals in it, namely, the old diatonic semitone 1·12, the *major* and *minor chromatic semitones* (as we will call them) ·92 and ·71, and the enharmonic interval (or enharmonic *diesis*, as it is called) ·41. And the major tone is in every instance

maj. chrom. semit. + min. do. + enh. int.

while the minor tone is

2 min. semit. + enh. int.

If we confound the major and minor tone (and to distinguish them is the *ultima Thule* of temperament), we must take a mean value, and substitute it both for the major and minor chromatic semitone. The mean tone is 1·9, which is to the diatonic semitone nearly as 5 to 3. The mean chromatic semitone is ·81, about $\frac{2}{3}$ of the diatonic semitone, and the enharmonic interval is its half. This is a well-known system of temperament (that of Huyghens): the octave being divided into 31 equal parts, five of them are a tone, three a diatonic semitone, two a chromatic semitone, and one the enharmonic interval. Introduce E♯ and C♭, which are omitted in the preceding, and we have the following for a tempered enharmonic scale, upon which we doubt of any improvement being practicable, without attempting the distinction between a major and minor tone :

C C♯ D♭ D D♯ E♭ E F♭ E♯ F F♯ G♭ G G♯ A♭ A A♯ B♭ B C♭ B♯ C
2 1 2 2 1 2 1 1 1 2 1 2 2 1 2 2 1 2 1 1 1

This system, however, is useless, inasmuch as instruments are required to have only twelve notes in the octave; but we should recommend the student to bear it in mind, as explaining those enharmonic changes which in piano-forte music are only fictions. This scale would enable us to play with equal correctness in all keys up to seven flats among the flats, and seven sharps among the sharps. Naming these keys by their principal notes, they are the keys of

C G D A E B F♯ C♯
F B♭ E♭ A♭ D♭ G♭ C♭

Now suppose an incidental deviation into the key of A♯. Looking into the preceding scale from A♯ ascending, we find we can get a whole tone at B♯, but the next whole tone is wanting, nor can we get it except by interposing a note between D♭ and D, two tempered chromatic semitones above C, and therefore called C♯♯ or C×. On the piano-forte we must be content with D for C♯♯, and accordingly we have in like manner

E for D♯♯, D for E♭♭, D♯ for F♭♭, &c.

In the preceding scale also, when enharmonic transitions are written, they can most frequently be actually made; on the piano-forte, though written, they can only be made in imagination. The ear, knowing what is coming, so soon as the enharmonic modulation is *seen*, prepares itself for a change of key, and gives the chord in its possession to the mind not altogether in the same way as when it was not a note of preparation. If any one will compare the effect of music heard the second time with that produced by the first time, he will, we think, be inclined to accede to our opinion, that sounds heard without any knowledge of what is to come afterwards, differ more from those which are heard with such knowledge than the effects of two scales constructed on the two most remote of all the approved systems of temperament. In Huyghens's system, his subdivision is ·387 of a mean semitone, the chromatic semitone is ·774, the diatonic semitone 1·161, and the tone 1·935.

The harmonics of any string C may be readily found from the table, reduced into the octave between C and C^1; they may then be compared with the untempered diatonic scale. For example, what is the 53rd harmonic of C? C itself counting as the first. It is by the table 68·73 mean semitones above C, lower this five octaves, by subtracting 60, and we have 8·73, lying therefore between A ♭ and A, but nearer to the latter.

[Chromatic Scale; Diatonic; Enharmonic. For Scales of Voices, Alto, Base, &c. For Scales of Musical Instruments, Bassoon, Clarinet, Harp, Violin, &c.]

SCALENE, a name given by Euclid, in his definitions (but seldom or never afterwards used by him), to a triangle no two sides of which are equal to one another.

SCAMMONY, properly so called, is, in the present day, the produce of *Convolvulus scammonia*, a plant growing in Greece and the countries along the Levant. The scammony of the ancients was in all probability yielded by *C. sagittifolius* (Sibthorp), *C. Sibthorpii* (Romeretsch), from which it is conjectured that the scammony called of Samos or Trebizond is obtained. The best comes from Aleppo; the next from Smyrna. The French scammony, called Montpellier S., is the produce of *Cynandum Monspeliacum*, an asclepiadaceous plant, endowed with most of the acrid and poisonous properties of that tribe, and therefore a dangerous substance. But even of the products of convolvulaceous plants the qualities are so various, either from natural inferiority, or, far more frequently, from carelessness in collecting it, or intentional adulteration, that no drug is more unequal in its constitution or more uncertain in its operation. Strictly speaking, it is a gum-resin; but the proportion of gum is at all times small, while the resin in different specimens varies from 81 per cent. in the best to 16 in the worst. Besides mechanical impurities, such as sand, fragments of the stem or roots, owing to the manner of collecting. chalk, and flour of wheat or barley, or dextrine, are purposely mixed with it to bring it down to the market price. The latter sophistications are not objectionable, further than they necessitate a larger and more bulky dose. But a most pure preparation can now be obtained by extracting the resin from the root itself, according to the patent plan of Prof. Williamson, suggested by Mr. Clark of Sockia, Asia Minor. (See 'Pharm. Journ.,' vol. xvii., p. 37; and vol. xviii., pp. 449 and 546.) For an account of the mode of collecting scammony in the north-west of Asia Minor, see the same Journal, vol. i., p. 522, new series, April, 1860. Perfectly pure scammony is, in a very small dose, a very efficacious purgative, clearing away mucous accumulations, more especially from the bowels of children, which are the favourite resort of worms. To expel these, scammony is often associated with calomel; but this is generally needless, as extract of rhubarb, from its bitter and tonic properties, is in every way more to be commended. By giving bitartrate or tartrate of potass, with carbonate of soda, its properties are heightened, and it may be rendered a useful hydrogogue cathartic. It should not be too frequently repeated, as it is apt to abrade the mucous covering of the intestines; nor should it be given in inflammation of these.

SCANDAL (*scandalum magnatum*, slander of great men). By the statute 2 R. II., c. 5, confirmed 12 R. II., c. 11, as to "devisers of false news and tellers of horrible and false lies of prelates, &c.," it was enacted that none devise or speak false news, lies, or other such false things of the prelates, nobles, and great men of the realm. By the same statute the tellers of such lies were liable, as by the statute of Westminster the first, to be imprisoned till they discovered the authors of them. No statutory punishment was provided against the authors, perhaps because they were liable at common law to fine and imprisonment. Upon this statute is founded the action of scandalum magnatum, which is now fallen into disuse, and superseded by the common action of libel and by the criminal information. It lies at the suit of any nobleman, though of a dignity created since the date of the statute, of the judges, and of other great officers of the realm. It has been held that the action may be brought not only for such words as are actionable in ordinary cases, but even for those which are not certain enough to maintain an action against a common person, as where one said, "My lord has no more conscience than a dog."

The object of the statute originally, though afterwards it appears to have been applied in private cases, was wholly of a political character. The mischief recited is that "debates and discords might arise betwixt the said lords, or between the lords and the commons, which God forbid, whereof great peril and mischief might come to all the realm, and quick subversion and destruction of the aforesaid realm." The statute of Westminster, 3 Edw., c. 33, referred to, is also directed to cure the same mischiefs, the discord and scandal that might arise between the king and his people, or the great men of the realm.

The term *scandalous* is applied to matter in a bill or answer in chancery which reflects on the character of a defendant or plaintiff, and is at the same time irrelevant. Such matter will be struck out on exceptions being taken to it and allowed.

(2 *Inst.*, 225; Com., *Dig.*, tit. 'Action on the case for Defamation;' B., *Libel*, C. 5.)

SCANDINAVIAN LITERATURE. The ancient Scandinavian language, once common to the whole north-western portion of Europe beyond the Baltic, is now confined to Iceland, where it has undergone little change since the 9th century. [Iceland, in Geog. Div.] This dialect of the Gothic is the parent stock of both Swedish and Danish, the former of which tongues has retained more of the original character than the other, which is also the language of Norway; and, if not for the literature they contain, in a philological point of view they deserve far more attention than they have hitherto obtained from Englishmen, since they throw considerable light on the history of our own language. There is also a striking similarity of construction between them and English, which renders them of comparatively easy acquisition to ourselves. Nearly the same grammatical simplicity prevails, nor are their verbs and nouns subject to those numerous changes of terminations which render such languages as the German and the Russian so perplexing to a foreigner.

Though literature, in the usual meaning of the term, was of exceedingly tardy development in both Denmark and Sweden, the people possessed an abundant stock of those traditional poetical records which scarcely lay any claim to individual authorship, being rather the embodying of the sentiments and feelings of an entire race than those of individuals. Of these, by far the most important are the Eddas. Though committed to writing by Bishop Sämund only in the 11th century, it is supposed that an earlier collection was then in existence. A part of Bishop Sämund's gathering has been lost, and what remains we owe to Snorri Sturluson, the grandson and pupil of Sämund. The elder Edda is in verse, not rhymed, but rendered metrical by the use of alliteration or assonance, in which the alliteration is employed twice in the first line of a couplet, and the second begins with the same letter. Many variations, including end rhymes, were subsequently introduced. The younger Edda is in prose, with a mixture of verse, partly quoted from earlier poems, in nearly every case from the elder Edda.

Though a distinction has been drawn between the elder and younger Eddas, there is little doubt but that some parts of the latter are at least equal in antiquity to some of those in the elder: and as little that in the elder Edda there have been many interpolations, which have been pointed out by Simrock ('Die Edda, die ältere und jüngere,' 1855), who, however, says, "Who would venture to lay hands on so reverend a piece of antiquity, and where would it end if each were to follow his inclination or caprice, and began to model the tradition according to his own notions." The elder Edda consists of thirty-seven poems, of various degrees of poetical merit, all relating to the mythology, which will be treated of in the next article. After being forgotten for nearly four centuries, a copy was found by Bishop Svensen, and published in 3 vols. 4to, containing the original text, a Latin translation, and a dictionary of the northern mythology, in 1787. A later and more correct edition has been since published by Rask in 1818.

The later Edda is divided into two books,—Gylfaginning, or Gylfa's fascination, and relates a like story to that of Vafthrudnismal (or song of Vafthrudni) in the elder Edda; but occasion is taken to deliver the principal doctrines of the northern faith in answer to the disguised Odin's inquiries. Bragaroedhur, or Bragi's Discourse, borrowed also from the Oegirsdrecka, or Oegir's Drinking Feast: here Bragi, the scald of the gods, discourses of the origin of poetry. These were first translated and published by Resenius in 1640. In some manuscripts, however, and in Rask's printed edition, these are accompanied by some of the Scaldaic songs. [Scald.]

Of other Scandinavian poems there are many distinguished by the title of Kämpe Viser, or Heroic Ballads, which strains of romantic minstrelsy serve to give an idea of the compositions of the ancient bards or scalds. Deeds of arms and bravery constitute their main subjects; for in the infancy of states personal courage and physical strength are regarded as the chief titles to pre-eminence, more especially in such a region as Scandinavia, where the sword was the only patrimony of the younger branches of a family, and was a possession quite as honourable and frequently more lucrative than that of the soil. Possessing a very great extent of sea-coast, the inhabitants regarded that element also as their natural territory. Their piratical expeditions, undertaken partly through necessity and partly from the love of adventure, obtained for them a fearful fame; and the leaders of these hardy pirates assumed the imposing title of Sea-kings. These 'Viser' contain moreover no small quantity of legendary fable and supernatural lore, derived from the ancient Sagas and the mythology of the Edda [Scandinavian Mythology], whose wild traditions were so congenial to the spirit of the people that they continued to cherish the remembrance of them long after the establishment of Christianity (which was not earlier than the commencement of the 11th century); and in modern times they have been largely made use of by Oehlenschläger and other living or recent poets, who have found in them a source of powerful interest for their countrymen. For a while indeed it was very doubtful whether the Gospel would prevail against the popular belief in the Valhalla. The labours of the early missionaries in the 9th and 10th centuries produced very little effect; the people continued to be almost entirely pagan, and Svend Tvæskæg, the successor of Harald, renounced Christianity, and did all he could to re-establish the worship of the ancient idols; nor was it until after the accession of Canute the Great (1014), that Christianity became the national religion, and churches and convents began to be built. For several years afterwards, however, little improvement took place in the intellectual condition of the people. Literature can hardly be said to have been cultivated at all. Its sole monument is the history (written in Latin) by Saxo Grammaticus, who died in 1208. In Germany, as well as in England and Scotland, where this literature and mythology were once predominant, both faded away more quickly under the influence of civilisation. Odin, or, as he was called by those nations, Woden, was forgotten, but the popular tales and fictions remained. The ballad poetry of Scotland retains many a lay identical almost with those of the Scalds; while Puss in Boots, Blue Beard, the Pig who would not go over the style, and Jack the Giant-killer, have their Scandinavian originals. Howitt's 'Literature and Romance of Northern Europe;' and Dasent's 'Tales from the Norse,' contain much that is interesting on the subject.

Of the modern literature of the Scandinavian nations, Iceland, Sweden, Norway, and Denmark, notices will be found in the BIOGRAPHICAL DIVISION, under the names of the more eminent authors.

SCANDINAVIAN MYTHOLOGY. The genuine and older Scandinavian mythology, which, in regard to wild imagination, sublime conceptions, a rough vigour, and a naïve simplicity sometimes approaching the ludicrous, will bear comparison with those of the Hindus, the Greeks, or Romans; and which, from the extensive influence it has exercised on all nations of Gothic and Teutonic descent, has a peculiar interest for them, is to be found in the Edda, a word meaning great grandmother, or rather ancestress, probably used to indicate that the cycle of poems, to which the name is given, had a more remote origin. As we have stated in the preceding article [SCANDINAVIAN LITERATURE], the Edda consists of two parts—the elder Edda, a cycle of poems, and the younger or prose Edda, which is chiefly a compendium of the elder, with occasional extracts from it.

The Scandinavian mythology comes to us, not in the shape of a religious system, so much as the poetical expression of some of the worshippers. It does not approach a system even so much as Hesiod's Theogony; for it has to be gathered from various poems or fragments of poems, of which some are manifestly of much greater antiquity than others. Some, no doubt, are of a period anterior to the Christian era; but as all were collected at a long subsequent period, it is probable that the belief in the destruction of the world and its renovation may have been derived from Christian sources. Thus the Edda presents in the very beginning the germs of one all-destroying catastrophe, of a creation which by necessity involves the final destruction of the universe, with a promise of a resurrection and a happier existence. This destruction has been long foretold.

The history of the Creation by the Asar has little resemblance to that of Christianity. In every creation by the heathen gods, the material stuff is always in existence. In the Asar creation, the world becomes a living organism. Nature is not a rude mass, she is not dead, but an organised whole, that is ever penetrated by a superhuman life. When this idea, which approaches to the pantheistic, is expressed in a poetically-material manner, we may compare it with other mythologies, in which, like it, giants, Titans, Cyclops, the original dwellers in Chaos, embody the unrestrained force of the elements till subjected to the might of a higher and regulating power. There is also the peculiarity of accepting the principle of evil as the first existence, to counteract which the principle of good was formed, or rather descended, for Odin's mother was a daughter of the giants.

In the beginning was a chaos. On the north was Niflheim, cold, dark, and foggy; on the south, Muspelheim, warm and light; betwixt these two was Ginnunga-gap, in which contended the ice and frost of Niflheim, the light and heat of Muspelheim, and into which flowed twelve streams called Elivagar, which were poisonous, issuing from the fountain Hvergelmir. This water, hardened by the frost, by degrees filled the gap; was again gradually melted by the warmer south; and the heat thus imparted at length produced Ymir, a being of enormous size and malignant disposition. Ymir fell asleep, and under his left arm grew a male and female; from his right hand and foot a six-headed giant. These were the progenitors of the race of giants. The ice continued to melt, and a cow, Audhumbla, was produced, by whom Ymir was nourished from its four milk-streams (the four elements). The cow, Audhumbla, licked the icy salt-stones, and on the evening of the first day arose the hair of a man, on the second his head, and on the third the complete man, handsome, large, and strong. He was named Buri, and had a son (no mother is mentioned) called Bör, who took to wife a daughter of the giant Bölthorn, and had by her Odin (or Odhin, the Woden of the Saxons), Veli, and Ve—the first of the Asar. These three having slain Ymir, carried the body to Ginnunga-gap, and with it therein formed the world: the blood became water; the flesh, earth; the bones, mountains; the teeth, pebbles; the hair, grass, trees, and other vegetation; the skull, the firmament; the brains, thrown into the air, became clouds; and of the eyebrows were made a wall of defence against the frost-giants. This round flat world was called Midgard, and was encircled by a deep ocean (sometimes typified by a vast serpent), outside of which was Jötunheim, the abode of the giants. With sparks of hot cinders from Muspelheim were formed sun, moon, stars, lightning, and meteors; and their courses were prescribed, thus forming night and day, and the seasons.

Asgard, the residence of the Asar, was apportioned into Vanheim, the domain of the elementary deities; Glad-heim, in which was Valhalla, where dwelt Odin and the deities of his family; Muspelheim, the district of celestial fire; and Licht-Alfheim (elves of light), the residence of the benevolent dwarfs, or elfs, in which also was situated Gimli, the place of future beatitude.

Utgard was under the earth, deprived of the sun's light, and was divided into Jötunheim, the country of the giants; Swart-Alfheim, that of the black dwarfs, or gnomes; Niflheim, in which was Hel, the residence of Hela, goddess of death; and Naströnd, a horrible swamp, inhabited by serpents, into which, at the end of the world, the wicked are to be thrown.

According to the Völuspá, the (three?) gods in council next created the dwarfs, who had been bred like maggots from the corruption of Ymir's blood, and who were now endowed with human shape, though often deformed; and they formed a counterpoise to the giants, who are represented as stupid, while the dwarfs make up for their want of size by their ingenuity, acuteness, and knowledge. They have still, however, to dwell in the earth or in rocks and caverns. The Völuspá and the prose Edda differ here, as the Völuspá says they were created from Brimir's blood. They also differ as to the next creation, that of mankind. The Völuspá says, after creating the dwarfs,—

> "Then the three went, From this assembly,
> Mighty and mild The Asar especially.
> They found on the sea-coast, Powerless,
> Ask and Embla, Without fixed destiny;
>
> Possessing no soul, Having no sense,
> Neither blood nor motion, Nor yet blooming colour.
> Odhin gave soul, Hönir gave sense,
> Lodur (Loki) gave blood and blooming colour."

In the prose Edda, as the children of Bör wandered by the sea-shore they found two trees, of which they formed the male and female, Ask and Embla: Odin bestowing on them life and spirit; Veli, sense and feeling; and Ve, visage, speech, hearing, and sight; and from these two are descended the whole human race. Jacob Grimm remarks on this ('Deutsche Mythologie') that only dwarfs and men are created; the giants and the gods come into existence as if of themselves, from the influence of merely natural forces; they owe their being to the union of fire and water, while mankind and the men-like dwarfs are made by the formative activity of the gods themselves acting with a purpose.

After the creation came the golden age of the Asar, till at length three maidens of the race of giants surprised them. They took away their golden table, and left instead a desire for gold; this led to a war with the Vanir, who had broken down the outer wall of Asgard; but a peace was at length concluded, when Hödur was given as a hostage on one side, and Niörd on the other, who received a seat and a dwelling in Asgard.

Ygdrassil, the tree of life, which forms so important a part of the cosmogony, is first mentioned very abruptly in the 'Völuspá,' and equally so in the 'Grimnismal' (song of Grimni). This tree has three roots, one in heaven, one in the residence of the Frost-giants, and the third in Niflheim or Hela. At each root was a fountain possessing wonderful powers, and its branches spread around the whole universe. At the root in Niflheim lives the serpent Nithhögg, constantly gnawing them, and in its topmost branches sits an eagle with a hawk between his eyebrows. A squirrel, Ratatoska, runs up and down, exciting strife between the eagle and the serpent; and on its branches browse four stags. The tree is an ash, and is the greatest and holiest of all trees, uniting heaven, earth, and the lower regions. The springs are also sacred. Round the heavenly Urdar-brunnen the Asar assemble every day to pronounce judgments, assisted by the three chief Nornen—Urd, Verdaldi, and Skuld. There are, however, many other Nornen, who decide on the length of life, and the good or ill-fortune of every individual of the human race, some of whom are descendants of the Asar, some, of the races of elves, and some of the race of the dwarfs. Every day the Nornen water the tree from the fountain, to keep it in vigour, and from its leaves falls the dew. The well of the giants is guarded by Mimir, an old and wise man, but whether god, giant, or demi-god is uncertain, and in this well lie hidden wisdom and knowledge. The third is Hvergelmir or the roaring basin.

The chief gods, who were especially to be worshipped, are twelve; the goddesses are fourteen. The subordinate superhuman powers are numberless. We only enumerate the chief, which are—1, Odin, who governs all things, and who is obeyed by the other deities, as a father by his children. Hence he is named Alfadir (All-father) and, with numerous other names, Valfadir, from having prepared Valhalla and Vingolf for the reception of the Einheriar (his selected heroes) who have fallen in battle. Near his seat in Hlithskialf are two wolves, which he feeds with the viands set before him, as he needs no food; and on his shoulders sit two ravens, Hugin and Munin (Thought and Mind) who whisper in his ear all the tidings they have collected. His wife is Frigga, who foresees all things, but never foretells them. 2, Thor, the mightiest and strongest of gods or men; possessing a hammer, Miölnir, of enormous power, which returns of itself to him after having been flung at any one; a belt by which his strength is doubled when it is worn; and gauntlets without which he cannot grasp the handle of his hammer. He was the son of Odin by Fiörgyn (the earth), who also figures as a male, the father of Frigga, the wife of Odin. Thor is the protector of the earth, whose cultivation he has established, whose fruitfulness and kindliness in favour of its inhabitants he unweariedly fosters and furthers, and is therefore in continual conflict with the wild elements. His wife is Sif, from whom by a trick Loki stole her hair, and was forced by Thor to supply its place with hair of gold. 3, Baldur, the second son of Odin by Frigga, the handsomest and best of the Asar, the wisest, mildest, and most eloquent. His wife was Nanna. He was early threatened with death, to guard against which every created thing was required to swear to do him no harm; but, instigated by Loki, his blind half-brother, Hödur (unreasoning strength), slew him by throwing at him a branch of mistletoe, which had been overlooked in the swearing. His fate occasioned the visit of Odin to Hela, which has been paraphrased by Gray. 4, Niörd governs the winds, stills the sea, and checks the fire. But he is not of the race of the Asar. Born and bred in Vanaheim, a district of the giants, he was given as a hostage to the Asar on a peace being concluded with the Vanen, who received from the Asar as a hostage on their part, Hödur, one of the joint creators of mankind. His wife was Skadi, daughter of the giant Thiassi. They had two children; a son named Freyr, and a daughter named Freyja, both beauteous and powerful. 5, Freyr governs the rain and sunshine, gives abundant harvests, promotes peace, and dispenses riches to men. He fell in love with Gerda, the daughter of Gymir, one of the giants in Jötunheim, and obtained her for his wife through the intervention of Skirnir, and this forms the subject of one of the poems of the elder Edda, Skirnirsfôr or Skirnir's Journey. His sister is equally benevolent, she assists all who desire her assistance, is especially favourable to lovers, and claims the half of all who fall in battle (the other half belonging to Odin), whom she entertains in Sessrumnir, her mansion in Asgard. 6, Tyr, whose descent is uncertain, is bold and courageous, promotes strife, and gives victory in war. He has but one hand, as the other was bitten off by Fenrir, the wolf, who demanded of the Asar the pledge of one of their hands in his mouth before he consented to be bound in order to try his strength. None of the Asar dared this but Tyr. The wolf remains bound until the day of the destruction of the world. 7, Bragi, celebrated for wisdom, eloquence, and his skill in poetry: he was the skald of the gods. His wife was Iduna, who had charge of the golden apples, by eating of which the gods renewed their youth. Loki by a trick delivered her and her apples to one of the giants; the gods became wrinkled and gray; and then Loki by another trick brought her and her treasure back to the Asar. 8, Heimdall is one of the Asar, the son of nine virgin sisters, but beyond the epithet *weisse Aes* (white Aes, singular of Asar) his descent must be admitted as obscure. He was a powerful god, and much honoured. He is the warder of the bridge Bifröst (the rainbow), requires less sleep than a bird, sees by night as well as by day, can even hear the grass grow on the earth, and the wool on the sheep's back. His horn when sounded is heard all over the world, and his sword fights of its own accord. 9, Vidar is one of the sons of Odin, and surnamed The Silent. He is next to Thor in strength, and on the day of combat against the giants is to kill the wolf Fenrir, by driving his sword down his open jaws. 10, Vali, another son of Odin's by Rinda, who undertook to revenge the death of Baldur, and assisted in binding Loki. 11, Ullur is the son of Sif, step-son of Thor, skilful with the bow, swift on snow shoes, handsome and brave. 12, Forseti, the son of Baldur and Nanna, celebrated for his correct judgments, from which all disputants depart satisfied. Other lists somewhat vary from this. Hödur, the blind and strong, has been mentioned, but seems not to be included among the twelve. The prose Edda says, "the gods might well wish they had never to name him, for too long will his deed remain in their memory."

Besides the Asar, there are some other important deities. One of the chief is Loki, one of the sons of the giant Farbauti and Nal, or Laufey, his wife; the others being Byleist and Helblindi. Loki is handsome in person, but capricious, cunning, and perfidious. He was at times the friend, and commonly the associate, of the Asar, but the continual contriver of mischief against them. He had a wife called Siguna, and a son by her named Nari, who was devoured by his brother, the wolf. But his most celebrated progeny was by the giantess Angurbodi, by whom he had the wolf Fenrir, who used to follow the sun, endeavouring to swallow it, whose binding has been already mentioned, and who will at length break loose, and assist in the destruction of the world; the serpent Jormungand, who was thrown by the gods into the deep ocean that surrounds Midgard, which he encircled, holding his tail in his mouth; and Hela, who was cast into Niflheim, and has power over nine regions, into which she distributes all who die through old age or sickness. The dominion of Hela is not a place of punishment, but only the abode of those not deemed worthy of dwelling in Valhalla. Loki himself is at length bound on sharp-pointed rocks, with a serpent suspended over him; whose venom should fall on his face, but his wife Siguna catches the drops in a cup till it is full; she then has to empty it; and while this is being done, the drops which fall on his face cause such extreme pains, that he writhes and causes earthquakes. He is thus to lie till the end of the world. Oegir, also called Gymir, is one of the giants, and has dominion over the sea. It will be seen that Odin's two brothers, Veli and Ve, have disappeared. At the end of heaven sits Hrässchwelger (corpse-devourer), one of the giants, in the shape of an eagle, and from the flapping of his wings proceeds the wind, according to the force of their motion. Surtur, another god or giant, who remains in Muspelheim, is only to appear at the day of destruction. All the monsters are loosed, whom he will lead to the conflict with the Asar, some are killed, but they remain conquerors. After this final combat, Surtur spreads flames over the earth, and all will be consumed. But Naströnd is formed, a place of punishment vast and awful, constructed of serpents, whose venom collects in floods, through which wade murderers, perjurers, and adulterers; but in the plain of Ida, where Asgard formerly stood, another earth will arise from the sea, and says the Völuspá—

> "I see a hall, Brighter than the sun,
> With gold covered, On Gimli's height;
> There will the worthy Princes dwell,
> And without end, Enjoy their honour;"

where Surtur's fire can no longer harm them.

The prose Edda adds, that a man and woman survive, hid in a forest, and fed with dew, who are to replenish the world; and the sun is to bring forth a daughter (the sun is feminine in the northern dialects) more lovely than herself. This seems to be an addition. This Edda, compiled by Christians, has much more of the Christian element than the elder, and is therefore less to be depended on as a faithful transcript of the ancient mythology.

Of the goddesses, besides those mentioned, the most prominent after Frigga, were—Saga (history), a favourite of Odin's; Eir, skilful in the healing art; Gefion, who is a virgin, and to whom belong all who die unmarried; Fulla, also a maiden, the attendant and confidant of Frigga; Freyja (already mentioned) was married to Odhur, who left her, and Freyja wept tears of gold. She bears several other names, which she assumed while seeking her husband, and was the possessor of a famous necklace called Brisinga; Siöfna, who turns the hearts of men and women to thoughts of love; Lofn and Vöra are also deities favourable to lovers; Syn, is door-keeper of the hall of the gods, shutting it against all who have not the right of entering, and likewise presides at trials in which anything is denied on oath; Snotra, the wise and courteous; Gná is the messenger of Frigga, riding a horse on which she glides through the air; Sol, so named by her father on account of her beauty, while her brother he named Mani (moon). This pride offended the gods, who made the sister the driver of the horses of the sun, and the brother those of the moon. There are other goddesses, such as the Valkyrien, who serve the mead in Valhalla, and are sent by Odin to every battle-field to select the slain and to give victory; the Nornen also assist in this latter office. Also, Jörd (the earth), Thor's mother, and Rinda, the mother of Vali, are reckoned among the goddesses.

In Asgard are the twelve heavenly palaces or abodes, of such extraordinary splendour, that the light of the sun or moon was not needed. Asgard is protected by an abyss crossed by a heavenly bridge, strong enough to bear the gods, but which will break under the weight of the giants. This is called Bifröst, and is the rainbow, formed of water, air, and fire, as shown by its colours. The water and air would have been sufficiently strong for the Asar, but the fire was added to guard against the giants. On the boundary between Asgard and Midgard stands Thrudheim, the dwelling of Thor, which forms a thirteenth. The twelve are: 1. Ydali, the valley of moisture, in which Uller, the son of Sif, and the step-son of Thor, dwells. 2. Alfheim, or Elfinland, inhabited by Freyr, the son of Niord, and, according to the prose Edda, by the elves of light (by which is thought to be represented the germinating powers of the sun's rays), who are to exist till the overthrow of the universe, and then to betake themselves to the higher heaven. 3. Valaskialf, Vali's watchtower, in which dwells Vali, the son of Odin and Rinda. Here was also built Odin's chief seat, Hlithskialf, from the elevated throne of which, he and his wife Frigga could overlook the whole world. 4. Söckvabeck (the stream of descent or depth), rushing with cold water, whence Odin and Saga (history) drink every day from golden vessels, and intoxicated with the precious drink, rejoice in the love that may be derived from the water-oracle. 5. Gladsheim (realm of joy), where is Idavölle (the field of business), because here are forged the arms with which the heroes disport. This is the gathering-place of the Asar; here are held the feasts and the combats of the souls of departed heroes who reside in Valhalla; they wander arm in arm with the virgin Valkyrien, whose love and unfading charms are the rewards of those who have received their kiss in battle, the sign of an invitation to the feast of the gods. In Idavölle both Valhalla and Vingolf are situated. The last is the residence of the Einheriar (or heroes), whose help is needed by the gods in their final contest against the inhabitants of Muspelheim, on the destruction of the world. Vingolf is a palace of gold reaching to the clouds. Before the gates of Valhalla lies the forest of Glasir, in which the trees bear leaves of red gold. But Vingolf is the sanctuary of the goddesses, where the half of the slain whom Freyja has chosen are immediately conveyed, while the other half are received by the Valkyrien in Valhalla. Lastly, in Idavölle is the seat of judgment, under the ash Yggdrassil, upon the actions of gods and men. Seats were here provided for the twelve gods already mentioned. In like manner, upon earth, courts of judgment were to be held under a sacred tree and near a sacred well. After having dispensed justice, the Asar ride on splendid horses. 6. Thrymheim (groaning or thunder-home), where dwelt the giant Thiassi, and after his death his daughter Skadi. 7. Breida-blik (world-glancing) the most magnificent of the heavenly dwellings, where is not the least soil, and which is Baldur's residence. 8. Himin-biorg (heavenly palace) on the border of the celestial region, where resides the wise god Heimdall, who is entrusted with the care of the bridge Windhjalm, from being possessed of the Giallarhorn, which is heard throughout the world, from his sleeplessness, and from his wonderfully acute senses; in order that the Asar may not be unexpectedly surprised, one end of this bridge, called Bifröst (rainbow), is close to Heimdall's abode. At the time of the destruction of the world, the invaders from Muspelheim will attempt the passage, the bridge will break or dissolve. 9. Fölknvangr (field of the combatants), the abode of Freyja; a splendid palace, surrounded by a beautiful garden, in which is the hall Sessrumer, wherein the fortunate, who have been selected by the benevolent goddess, enjoy every bliss the world can bestow. 10. Glitnir (splendour), the palace of Forseti, resting on golden pillars, the windows of diamonds, and the roof covered with silver. 11. Nöa-tun (Newcourt), the palace of Niord; and 12. Landvidi (Broadland), overgrown with long grass, that of Vidur.

That under the symbols of these twelve palaces, the twelve months, or the zodiacal signs, are to be understood, there can be little doubt, though it has been controverted, and although we are unable to decide which month or sign the various palaces are meant to represent.

In Asgard the gods had placed their dwellings in the earliest times (Urzeit), and they will all perish in the general conflagration. But this conflagration, though destroying everything, is to give birth to a new creation, in which Asgard will re-appear with increased splendour, and the Asar will revive to resume their original powers. Odin and Thor only will disappear, and the late palace of Odin will become, after this terrific crisis, the abode of Baldur and Hödur. In the first poem, the Völuspá (the decision or judgment of the Veli or prophetess [*]), it is said,—

> "The sun becomes black, The earth sinks in the sea,
> From heaven fall The bright stars,
> A fiery vortex rages round The all-nourishing world's tree,
> The hot flames Lick the skies."

After which the Asar are to reassemble, to find fields that bear produce without sowing, whence everything evil has vanished; and

> "There ride the mighty To the council (or judgment) of the gods;
> The great above all, Who guides all things.
> He decides disputes, Appeases quarrels,
> And ordains for ever His institutions."

Of this "great above all," the 'Hyndluliódh' (the song of Hyndlu) says, after having given a genealogy of the Asar:—

> "Then comes another, Mightier than he,
> Yet him to name I do not venture.
> Few would wish Further to look
> Than when Odin The wolf attacks."

We shall not attempt to give any of the legends incorporated with this system, nor with the esoteric meaning. On the whole it will be seen that the deities are personifications of physical forces and of human passions, fashioned by a northern imagination. J. Grimm, in his 'Deutsche Mythologie,' endeavours to prove that the northern deities are nearly identical with the Greek and Roman and the Hindu deities. There are, necessarily, points of resemblance, but sufficient differences to render the conceptions in each case original.

The Hawamal, or High Song, contains the ethics of the system; there are many striking sayings in it, but we cannot do more than give a specimen:—

> "With his weapon No one should part
> In the open field;
> No one knows, How soon on the way
> He may need his spear."
>
> "Moderately wise Should a man be
> But not too wise;
> The heart of the wise Is seldom serene
> If it becomes too wise."

For a fuller investigation we may refer to Jacob Grimm's 'Deutsche Mythologie,' 1854; Karl Simrock's 'Die Edda, die ältere und die jüngere,' 1855; and 'Das Mythologische Handbuch,' 1853; L. Uhland's 'Sagenforschungen. Der Mythus von Thor,' 1836; Berger's 'Nordische Mythologie,' 1834; Dr. J. C. Bauch's 'Nordische Mythologie,' 1847; Rask's 'Snorra Edda, ásamt Skalda ogtharmeth fylgjundi Ritgjorthum,' Stockholm, 1818; various papers by Uhland, Dietrich, Müllenhoff, Grimm, and others, in 'Zeitschriften für Geschichtswissenschaft;' Mannhardt's 'Germanische Mythen;' W. G. Frye's 'Trois Chants de l'Edda,' Paris, 1844; and Mallet's 'Northern Antiquities,' edited by I. A. Blackwell, 1847.

SCANTLING, a term used by carpenters to express the transverse dimensions of a piece of timber; and also in some cases as a general name for small timbers, such as the quartering for a partition, rafters, purlins, or pole plates in a roof, &c. All quartering or squared timber under five inches square is designated scantling. [TIMBER.]

In masonry the same word is used to express the size of stones in length, breadth, and thickness.

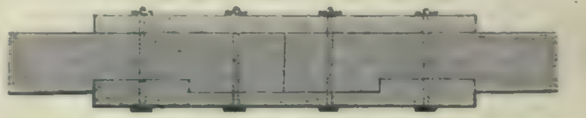
SCAPEGOAT, or AZAZEL (עֲזָאזֵל). On the great day of atonement among the Jews, the high-priest was to choose two goats, and after presenting them before the Lord at the door of the tabernacle, he was to cast lots upon them, one lot being for the Lord, and the other "for Azazel." The one upon which the Lord's lot fell was to be sacrificed as a sin offering, and the other was to be presented alive before the Lord to make an atonement with him, which was done by the high-priest laying both his hands on the head of the goat, and confessing over him the sins of all the people, which were thus said to be "put upon the head of the goat." The goat was then to be sent away into the wilderness by the hand of a fit man, who was to let him go in the wilderness. (Levit., xvi. 8-28.)

The meaning of the word *Azazel* is very doubtful. It seems to be derived from a root (which still exists in Arabic) meaning *to separate*. 1. The common interpretation refers it to the goat itself as being *sent away*. 2. Some take it to be the place to which the goat was sent, as being either a proper name, or merely a general term for a *separate place* or wilderness. 3. Spencer and most of the German critics consider it to be the name of an evil spirit, who was supposed to inhabit desert places; and they would translate Levit. xvi. 10, "to let him go *to Azazel* (instead of, *for a scapegoat*) into the wilderness." 4. It is maintained by Hengstenberg and others, that Satan is typified by the goat, the separated one, and this view seems corroborated by the passage in Zech. iii. Representing the sins of the people, which are upon repentance to be forgiven, he is driven away into the desert. It is also considered to be typical of Christ, so far as a vicarious atonement is to be accepted under certain conditions for committed sins.

SCARFING, the mode of joining two pieces of timber end to end, in such a manner that they may appear but one, and cannot be pulled asunder by a force applied in the direction of their length, without breaking off part of the wood at the joint.

Other modes of uniting two timbers into one continuous length are sometimes practised; as for instance, the simple plan called *fishing* a beam, in which the ends abut against each other, and pieces of wood are added on each side, as shown in *fig.* 1; the whole being held together by iron bolts. The strain on the bolts may be reduced by indenting the pieces added at the joint into the beam, as represented in the lower part of the figure; or by transverse keys of hard wood driven into grooves, of which one-half is cut in the beam, and the other in the supplementary pieces, in a similar manner to those shown in *fig.* 6.

Fig. 1.



Where neatness is more essential than strength, scarfed joints are preferred to any arrangement of this kind, because a beam united by them is of the same breadth and depth at the joints as at other parts. *Figs.* 2 and 3 represent two of the simplest forms of scarfing, in both of which the strain is borne wholly by the bolts. It is advisable to add a plate of iron on the faces of the beam where the heads and nuts of the bolts pass through, and the ends of these plates may be turned into the wood, as shown in the cuts. Of these two plans the first appears rather preferable, because the screwing up of the bolts has no tendency to alter the position of the parts; while in the second it has a tendency to make the inclined faces slide upon each other, and thereby to open the joint.

Fig. 2.

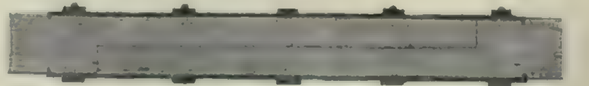
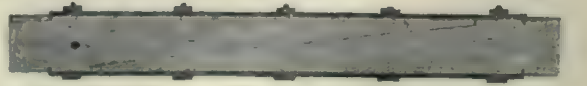


Fig. 3.



It is desirable to avoid depending solely upon bolts for the strength of a scarf, owing to the effect of the shrinking of the timber, and the liability of the bolts to be, in consequence of their small dimensions, pressed into the wood. *Fig.* 4 is a scarf that may be used without

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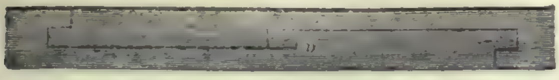
[*] The form of the word is perhaps deserving of a notice, as giving the origin of the Scottish word *spae*, to foretell; and *spaewife*, a fortune-teller.

Fig. 4.



bolts, although the addition of them adds much to the security of the joint. In this plan a key or wedge is driven gently into the square space at *a*, to bring the parts into their places. Two other illustrations will suffice to explain other varieties of scarfing. *Fig.* 5 is a diagonal scarf, in which the parts are said to be *tabled* together; they being so cut and fitted to each other that no force can separate them longitudinally, without breaking, so long as the bolts hold them together sideways. *Fig.* 6 shows a very simple and good plan of scarfing, which is easily executed with accuracy, owing to the absence of oblique faces. In this arrangement keys are used to resist any force tending to separate the beam in the direction of its fibres, instead of the parts being tabled together. The ends of the keys, which should be of hard wood, and let into both pieces of the beam to an equal depth, are shown by the dark tint in the cut.

Fig. 5.

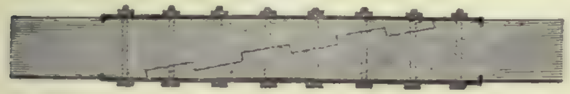
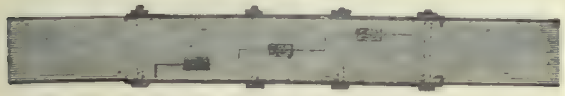


Fig. 6.



Varieties may be almost infinitely multiplied by increasing the number of the faces, whether oblique or square, and uniting the parts either by tabling, keying, or a combination of the two; but in most cases the greatest simplicity should be aimed at, in order that the parts may the more readily be made to fit each other with accuracy. Very complicated scarfs have been used by some old carpenters, respecting which Robison observes that "many seem to aim at making the beam stronger than if it were of one piece;" an absurdity too manifest to need refutation. Where a scarfed beam is exposed to transverse strains, the joint should be varied from the ordinary form; but for these and some other contrivances to meet peculiar circumstances the reader is referred to the practical works of Tredgold, Nicholson, &c. When a piece of timber subject to compression in the direction of its length has to be scarfed, oblique faces should be avoided, because of their tendency to slide upon each other. Though bolts are commonly used to secure scarfed joints, iron hoops or straps, driven on tightly, have been recommended in their stead, and possess the advantage of not weakening the timber. In joints that depend wholly on bolts, Tredgold recommends that the sum of their areas should never be less than two-tenths of the area of the section of the beam. From the same authority we give the following rules for the length of scarfs:—

In oak, ash, or elm, the whole length of the scarf should be six times the depth or thickness of the beam, where there are no bolts.

In fir, without bolts, twelve times the depth.

The whole length of a scarf dependent wholly upon bolts should be in oak, ash, or elm, about three, and in fir, six times the depth of the beam.

When bolts and indents are used together, the length of the scarf may be, in hard woods, twice, and in soft woods four times the depth.

SCARIFIER. [ARABLE LAND.]

SCARLATINA (originally written Scarlattina, from *scarlatta*, a red-coloured cloth), Scarlet fever. This disease was not distinguished by the ancients from any of the other eruptive fevers; they contented themselves with classing together all these fevers as pestilential, and they attributed the variety of eruptions that accompanied them to different combinations of the humours. Small-pox, measles, and scarlatina were described by the Arabians, but they looked upon them merely as varieties of the same disease, and even to the close of the 18th century the two last-named maladies were confounded. Dr. Withering, in a second edition of an essay which he published on scarlet fever, in the year 1793, first pointed out its distinctive characters.

Scarlatina, like small-pox and measles, may appear as an epidemic, or it may be propagated by a specific contagion; as an epidemic, it most usually appears at the latter end of the summer and the beginning of autumn; sporadically, it is met with at all seasons; it further resembles the diseases we have just named in rarely attacking twice the same individual. Scarlatina varies much in severity, from the mild febrile disturbance which has been pronounced by Sydenham to be fatal only through the officiousness of the doctor, to that grave form of the disease which has received the appellation of malignant. This difference has given rise to its division into three species, the *Scarlatina simplex*, *S. anginosa*, and *S. maligna*. Scarlatina is ushered in by rigors, followed by increased heat of the body, thirst, loss of appetite, and all the symptoms of inflammatory fever. On the second day of this fever, or somewhat later in the severer forms of the disease, patches of a scarlet-coloured efflorescence begin to appear on the face and neck, which extend downwards, and, coalescing, soon spread over the whole body. On the trunk, however, the rash is seldom uniform, but is distributed into diffuse irregular patches, the scarlet hue being most vivid about the flexures of the joints and on the loins; occasionally minute vesicles are visible, and Sauvages has considered this circumstance sufficient to constitute a distinct species, which he calls *S. variolodes*. On the third and fourth days the eruption is at its height; even the mouth and fauces are not free from it, the papillæ of the tongue are unusually red and elongated, and the face is generally more or less swollen. On the fifth day it begins to decline, disappearing by interstices, so that the patches reappear as at the commencement, and it is generally gone before the end of the seventh. Between the eighth and twelfth days the cuticle comes off in the form of a scurfy desquamation, and the fever has subsided. This is the course of *Scarlatina simplex*. At those periods of the disease when the eruption is in patches, scarlatina is apt to be mistaken for measles, but it may readily be distinguished from the last-named disease by the following signs:—In measles, the patches are of a rosy hue, of a crescentic form, and elevated above the surrounding skin; in scarlatina they resemble more the colour of boiled lobster, want the crescentic shape, and the hand passed over them detects minute asperities, but no elevated patches. It is further distinguished from measles by the greater heat of skin, the temperature being sometimes as high as 108° or 112° of Fahr., by the absence of catarrhal symptoms, and by the state of the papillæ of the tongue.

Roseola is the name of an affection which is characterised by an eruption bearing some resemblance to scarlatina; but it is of a more crimson colour, pursues its course in a direction contrary to that of scarlatina,—namely, from the extremities and trunk to the neck and face,—and is attended with less constitutional disturbance.

Scarlatina accompanied with sore throat—*S. anginosa*, or *cynanchica*, as it is termed—is a much more frequent and severe form of the disease than that which we have just described. Not only are the precursory febrile symptoms more violent, but the whole course of the malady is protracted; the eruption is seldom so universal as in the simple variety, but is in scattered patches, which frequently vanish and reappear; the interior of the mouth and fauces is of a high red colour, tumefied and painful; superficial ulcerations not unfrequently form on the tonsils, uvula, and soft palate; and the throat is much clogged up with a tough viscid phlegm. In *S. maligna* the fever is of a typhoid character; the pulse is small and feeble; the tongue and lips dry, and encrusted with a brown fur; there is delirium alternating with coma, and the rash is faint and continually coming and going; the ulcers in the throat are covered with dark-coloured sloughs, and a large quantity of viscid mucus clogs up the fauces and impedes respiration and deglutition. These symptoms are often accompanied by diarrhœa, and by petechiæ on the skin, with hæmorrhage from the nose, throat, bowels, or other parts, which generally lead to a fatal termination: this may occur on the third or fourth day of the disease, or the patient may linger to the second or third week; if recovery take place, it is exceedingly tedious. It has been observed that during the prevalence of scarlatina adults are not unfrequently affected with the efflorescence in the mouth and throat, without the skin participating in the affection. For this class of cases Dr. Tweedy has proposed the name of *S. faucium*. All the varieties of scarlatina that we have mentioned may be observed during the prevalence of the same epidemic, and even among members of the same family; but it is no less true that each epidemic has generally a certain character or type, which it is important to ascertain in order to regulate the treatment. This circumstance renders it difficult to come to any just conclusion as to the mortality from this disease.

The reports of the Registrar-General for 1858 and 1859 show the mortality in London from scarlatina as compared with other forms of zymotic disease:—

Diseases.	1858.	1859.
Scarlet fever	4118	4197
Small-pox	247	1156
Measles	2383	1305
Hooping-cough	2700	1741

Scarlet fever visits certain districts as an epidemic, and that whilst in some years it falls down to a level with other diseases of the same general nature, or even below them, it rises at others far above them. During the years 1857, 58, 59, and 60, scarlet fever has prevailed in London as an epidemic, and has carried off little short of 12,000 persons. During these years it has been associated with the disease called diphtheria, but they are distinct diseases and not in any manner produced by the same causes. [DIPHTHERIA.]

Scarlatina is often followed by other forms of disease. One of the most frequent of these is anasarca, which frequently terminates fatally.

This disease arises from the morbid condition of the kidneys. In a large number of cases of scarlatina the kidneys are primarily affected, and the urine presents a low specific gravity, and contains albumen. In the anasarca which comes on after the febrile symptoms have passed away, there is invariably present albuminuria. This condition of the system often terminates fatally by dropsical effusions occurring in the pleura, the pericardium, or the membranes of the brain. It sometimes happens that an attack of scarlet fever may not obviously produce the usual skin and throat symptoms but expend all its force on the internal organs, especially the kidneys. Under these circumstances anasarca may come on and lead to a fatal result.

Amongst other sequelæ or results of the action of the scarlatinal poison is an extension of the inflammation of the throat into the eustachian tube, and the internal ear. In this way the bones of the ear are destroyed, and ulceration of the tympanum and its destruction follow. Fœtid discharges take place, and the whole of the internal ear not unfrequently becomes involved, producing, should the inflammation not extend to the brain and destroy the patient, permanent deafness.

In other cases an affection of the joints, not unlike rheumatism, comes on during the attack of scarlet fever. This affection of the joints continues sometimes a long while after the active symptoms of the fever have disappeared.

Scarlatina is an example of a contagious and infectious disease. In the majority of cases the origin of the disease can be traced to exposure to the poison arising from a previous case. The intensity of the poison seems greater than even that of small pox or typhus. Dr. Watson says, "it lurks about an apartment, or clings to furniture and clothes, for a very long time, even after some care has been taken to purify them. Of this I have known several remarkable examples. You will be asked at what period the danger of imparting the disease on the one hand, or of catching it on the other, is over; and I would recommend you to answer that you do not know. I am sure I do not." Many persons go through life without catching this disease, and it is most desirable that all should. The only certain way of avoiding it is the strictest quarantine. Any thing which has been near the patient, or handled by persons attending upon the patient, may communicate the disease. The only certain prevention of its spread in families is either the removal of the sick or those liable to take the disease. The spread of the scarlatinal poison is not dependent on dirt and squalor, and other circumstances injurious to health, although the fatality of the disease is greatly increased by these circumstances. The disease is generated and spread by the poison alone. It is on this account that the greatest attention should be paid in nursing this disease to prevent infected things from passing out of the patient's bedroom. All linen or clothes worn by the patient should be immediately after they are used placed in boiling water. All vessels used in the bedroom should be immediately emptied after they are used, chlorinated lime or soda, or the permanganate of soda, being added to their contents. The vessels should also be washed and rinsed out with solutions of these substances. After the patient has recovered, every thing in the room that can be placed in boiling water should be submitted to its action, and books, papers, and things which will not bear water, should be placed in an oven. The room should be fumigated with chlorine, and the walls and ceiling whitewashed.

In the treatment of scarlatina it should be remembered that in the milder cases little or no medicine is required. The patient passes through all stages with little derangement of the system, and the only thing required is to prevent exposure to cold, and to watch for the accession of any of the symptoms of the sequelæ above mentioned. When the symptoms are more severe an alkaline treatmemt may be recommended. Dr. Watson especially recommends the chlorate of potash with hydrochloric acid. When the throat symptoms are severe in adults, leeches to the throat or cupping at the nape of the neck have been strongly recommended. Some practitioners recommend, in cases of a low type, small and often repeated doses of sulphate of quinine. Where the pulse is rapid and the tongue becomes dark, the administration of wine is indicated, and where wine fails to stimulate sufficiently, brandy has been given with advantage. The sesquicarbonate of ammonia, in cases with low symptoms, has been vaunted as a specific: it may be given with advantage in cases in which wine is indicated. Purgatives and saline diaphoretics may be administered as the symptoms indicate. The throat demands especial attention: where the tonsils are merely swollen a gargle of alum or powdered alum may be applied. When it is ulcerated the ulcers may be touched with nitrate of silver or a lotion applied. The chlorate of potash, with nitrohydrochloric acid, may be used as a gargle. Where the ulcerations are fœtid, syringing the throat with a lotion of chlorinated lime or soda will greatly contribute to the comfort of the patient. There is no one system of treatment that is adapted for all cases, and those writers who advocate one system can have had but little experience of the great variety of forms which the disease presents.

The treatment of the anasarca and other sequelæ will depend on the symptoms present. When dropsical effusion comes on, the patient will bear more active treatment than in the primary and secondary stages of the disease. Cupping or leeches to the loins is of service, and active purgatives. The chlorate of potash may be continued in this form of the disease, and when the more formidable symptoms are subdued, the salts of iron may be administered.

(Bennett, *Principles of Medicine*; Hood, *On the Fatal Diseases of Children*; Watson, *Lectures on the Practice of Physic*; Aitken, *The Science and Art of Medicine.*)

SCARLET DYE. [Calico Printing; Cochineal; Dyeing.]

SCARLET FEVER. [Scarlatina.]

SCENE PAINTING. With respect to the stage of the ancient theatres very little is known, and even that is exceedingly indistinct, being founded not upon description, but merely on incidental allusions. But granting that they employed some kind of temporary stage decoration suited to the subject of the piece, the presumption is that it did not at all resemble our modern scenery. The width of their stages renders it difficult to understand how any scene painted upon a single piece of canvas of sufficient size could have been let down, or rather drawn up, as it is supposed the *aulæa* were, or otherwise changed during the performance; and it is quite certain that, since the performances took place in the open air and by daylight, however contrived or executed, any kind of scenery like that of our modern theatres could not have produced the same degree of illusion.

With the rise and progress of scene-painting and stage-effect in modern times we are not much better acquainted, since no specimens of early scenery have been preserved, and only scanty, casual, and fragmentary notices relative to it have come down to us. From what is recorded of Baldassari Peruzzi's [Peruzzi, in Biog. Div.] works of this class, and those of some other artists, it would seem that scene-painting was very greatly improved, though it may not have been brought all at once to perfection, about the time of Leo X. Considerable improvement appears also to have taken place in the general economy of the stage and everything connected with scenic apparatus, as well as in scene-painting. For much of his reputation with his contemporaries Inigo Jones was indebted to the fancy and talent he displayed not merely as a scene painter, but in getting up pageants and masques, and planning the decorations and machinery for them. But with respect to the nature of his scenic effects and contrivances, we have little more than traditional report to depend upon, for there exists no history of theatrical painting and of the various improvements which have from time to time taken place in the decorations and apparatus of the stage.

Of this last, and of the quantity of hidden machinery requisite for expeditiously changing the scenes, as well as for effecting more complex displays in pieces of *spectacle*, we shall not here speak, but confine our remarks to the painted scenery alone. Beginning with what is technically termed the *drop-scene*, as being the simplest of all, we have merely to remark that it is no more than a picture or single painted surface let down by way of blind or curtain between the acts, so as to close up the opening of the proscenium. As it generally continues to be used for an indefinite time—thirty or forty years in some instances—the drop is more carefully executed than back scenes, which, showy as they may be in effect, are required only for a season, and are at a much greater distance from the spectators. As far too as pictorial effect and truth of perspective are concerned, a drop shows itself to far greater advantage than other scenery, which is composed of different pieces constituting what is called a set of scenes. These consist of the narrow upright pieces called *side-scenes* or *wings*, of the narrow horizontal ones (*hanging-scenes* or *soffits*, painted to imitate a sky or ceiling, but chiefly intended to screen the space over the stage), and of the *back-scene*. Backs again are of two kinds, namely, *rolling* scenes which are let down from above, and *flats*, which are formed of two sliding scenes strained upon framing, like the wings, and meeting each other and uniting in the centre. These are employed when what are termed *practicable* scenes are required, that is, with doors, windows, &c., which admit of being used as real doors, &c.; or else when there is occasion that the "flat" should suddenly open and discover another scene behind it. In addition to these, there are what are termed *open* flats, which are scenes cut out in places so that both the background is seen and the actors can pass through them. They are commonly used for the representation of groves or forests, but sometimes for interiors with open arches. There are besides what are technically known as *pieces*, narrow scenes placed obliquely on one side of the stage when it is wanted to show a cottage or corner of a house, with a *practicable* door in it. Lastly, there is *set scenery*, as it is termed, where, instead of the usual wings ranged one behind the other, there is a single scene on each side extending from front to back, so that the stage is completely enclosed. By this means a more perfect representation of a room can be obtained than where wings are employed.

In fact side-scenes or wings can be regarded as little better than so many detached screens absolutely necessary to shut out from view the space on each side of the stage, since in themselves they rather detract from than at all aid illusion and effect; more especially in interiors, where what should represent a continuous wall or surface on either side is broken into several pieces, which are besides placed parallel to the back scene or flat, instead of being at right angles to it. If the scenery be viewed exactly from the centre and from the true perspective distance, the defect thus occasioned is not very striking or offensive; but if the spectator be near to the stage, or placed on one side of the house, the whole becomes more or less distorted, and the wings appear to be only so many disjointed fragments, so that all scenic illusion is destroyed.

Scene-painting is executed in *distemper*, that is, with colours mixed up with size, the design being first made in a sketch, which is accurately laid down to scale, and from which the perspective outlines are transferred to the larger surface. Instead of beginning with dead colouring and then gradually working up his picture, the artist puts in all his effects at once, (as in fresco-painting)—the full tone of the lights and shadows, finishing as he proceeds, and merely retouching or glazing those parts afterwards which require additional depth or brilliancy. In this kind of painting, *bravura* of execution and strikingness of effect are indispensable, and nature must be rather exaggerated than the contrary; at the same time care must be taken lest mere gaudiness be substituted for brilliancy and richness. Further, as much of the costume of the piece depends upon him, it is important that the scene painter should not only be skilled in architectural delineation, but also well informed as to the styles of different countries and periods, so as to avoid those errors and anachronisms which are frequently committed, and which are sometimes so glaring that no beauty of execution can atone for them.

Much of the effect of scenery depends upon a skilful mode of lighting it; in which respect considerable improvements have taken place of late years, and the light is now occasionally thrown from above, as well as from the sides and the foot-lights, coloured glass and other contrivances being also occasionally employed. A variety of mechanical contrivances have indeed been brought to great perfection so as to imitate particular effects in the most deceptive manner, such as those of moonlight, where the moon breaks through the clouds and gleams upon water, &c., changes of the sky from clear to stormy, or the contrary, the sudden glare of fire, &c.; the most elaborate and costly combinations of mechanical apparatus with carefully painted scenery are now exhibited in the "transformation scenes" of Christmas pantomimes and extravaganzas.

Though looked upon as a very subordinate branch of the pictorial art, many artists of superior ability have applied themselves to scene-painting. To the name of Peruzzi we may add those of Bibiena, Servandoni, Loutherbourg, Lambert, Rooker, Gonzago, Quaglio, Sanquirico, Stanfield, Roberts, Grieve, and Beverly.

SCEPTIC (Σκεπτικός), one who doubts, who deliberates, who circumspects. Such is the primary meaning of the word, but like most words it has been wrested from its primary signification by ignorance or prejudice, and is now, beyond its philosophical meaning, used to express a dissenter from an established religion. In one sense it denotes a philosopher; for doubt is the first step in science; it is the refusal to take for granted any explanation of phenomena that may be offered, and the *circumspection* of the grounds and truth of this explanation. In common usage, Sceptic denotes, loosely enough, an atheist, deist, pantheist, &c., or, more precisely, the holder of any heterodox opinions. Common usage is here, as is usually the case, wrong. To set the matter in its true light, we must remark that scepticism is simply doubt, while heterodoxy is disbelief; something manifestly distinct from doubt, which is a mere oscillation of the mind between opinions; the belief of this moment passing into the contrary belief of the next; whereas disbelief is the belief in something contradictory. Reid, and others of the Scotch school, class disbelief as an independent power of the mind, equally with belief. We hold that the two are one and the same power exercised on contrary opinions. The mind must believe a thing or disbelieve it (that is, believe something else which is contradictory), or must oscillate—one moment believing this thing, and the next believing another thing. If then this distinction be borne in mind—if we have rightly demarcated doubt from disbelief—the erroneous application of sceptic in common usage will be obvious. An unbeliever and an infidel are convertible terms in ordinary language; but nothing can be more erroneous. An unbeliever, in a positive sense, is the believer in some *other* religion, and as dogmatic in his belief as the most orthodox (and hence the early Christians were called atheists by the Greeks, because they disbelieved in *their* gods), and might turn round upon the orthodox believer with the charge of unbelief in *his* religion. Thus a Mohammedan is an unbeliever to the Christians, and *vice versa*. An *Infidel*, on the other hand, as the word implies, is one with no belief, a doubter, a sceptic. The Infidel, when truly such, does not dissent because he believes something else—not because he has a contrary faith—but because he cannot believe for any length of time either the one or the other; he oscillates between them This last is the true sceptic; this he always remains; he doubts, he deliberates, he circumspects to the last day of his existence: as soon as he ceases to doubt, deliberate, and circumspect, and takes up a distinct faith his character as a sceptic vanishes; he becomes a believer. When considering the great and awful subjects of religion or philosophy, the weakness of the human mind must ever keep it in this state of scepticism, when once it has renounced its faith in things higher than its own logic,—when once reason is set up as the standard, measure, and exponent of all things, the human being is lost in the shoreless sea of scepticism.

In one sense, there are few who are not sceptics on certain points and on the other hand, few who can properly be designated as sceptics; for to deserve this they must *continue* in the state of doubt which admits of no affirmation. Most men begin, as was said of Descartes, in doubting everything, and end in believing everything. The few who have consistently preserved the character of sceptic have been among the most celebrated in the history of philosophy. [SCEPTICISM.]

SCEPTICISM (Σκέψις), doubt, deliberation, circumspection. There are two significations to this word: the one denoting doubt of *an* explanation of phenomena; the other the more precise indication of a certain class of philosophers who have *continued* sceptics, whose system of thought in its fundamental points ever remained sceptical. To this latter we alone direct ourselves.

Socrates has been commonly called the founder of this sect by the enunciation of his famous tenet,—all he knew was that he knew nothing. But this was more a limitation of the confidence of the Dogmatists and Sophists, and a confession of the weakness of the human understanding, than any fundamental scepticism, such as was subsequently embraced by Pyrrho and others; for though Socrates, more occupied with pulling down than building up, advanced few speculative opinions of his own, yet we agree with Schleiermacher in awarding to him the merit of having first posited the true idea of science (as the intercommunion of dialectics, physics, and ethics); and this one positive principle in his philosophy is sufficient alone to demarcate him from the sceptics. As well might Bacon be accused of scepticism, his position in the 'History of Philosophy' being very similar to that of Socrates. How different this is from the scepticism of Pyrrho, whose whole philosophy consisted in a suspension of judgment, or perpetual negation [PYRRHO, in BIOG. DIV.], may be seen by a comparison with some definitions of scepticism by the philosophers themselves. Sextus Empiricus, the historian of the sect, defines it as "the power (δύναμις) of opposing in all their contradiction the *sensuous representations* and the *conceptions of the mind* (φαινόμενα τε καὶ νοούμενα), and thus to induce perfect suspension of judgment" (Sextus Emp. 'Pyrrho. Hypot.,' i. 1, 4); and Carneades denied the possibility of real knowledge of anything from the twofold relations of the representation (image-idea, φαντασία) to the object (τὸ φανταστόν), and to the mind (ὁ φαντασιούμενος), as the mind had no criterion of the truth: all that could be affirmed was the mere probability (τὸ πιθανόν). Ænesidemus defines it as the recollection of opinions from the testimony of the senses or other evidence, by which means one dogma was opposed to another, and upon comparison all found useless and confused. (Brucker, 'Instit. Philos.,' ii., c. 14, § 7.) From the fallaciousness of sense, the differences of sensuous perceptions in different organisations, the weakness of understanding, and the impossibility of diving beneath the appearances to the real causes of things, the sceptics deduced a system of indifference which became equally difficult to accept or refute. They maintained that every proposition requires a prior proposition to support it, and so on *ad infinitum*; or else it assumes some axiom which cannot be proved, and is to be taken for granted without demonstration, and consequently may be denied with the same force with which it is assumed. Further, that nothing can be known by means of itself, nor by means of something else, whilst that other remains unknown, and that other must either be unknown or known by means of something else, and so on *ad infinitum*. (Sextus Emp., i. 15.) This last is extremely subtle, and in itself is irresistible; but as Kant profoundly remarked, there is this fundamental flaw in absolute scepticism, "that it gives out everything for appearance. It therefore distinguishes appearance from truth, and of course must have a mark of distinction; consequently presupposes a knowledge of the truth, thus contradicting itself." The careful avoidance of any expression savouring of certainty—the using of the term *seems* for *is*—which was adopted by this sect, has been inimitably ridiculed with all his wit and vivacity by Molière ('Mariage Forcé,' act. i., sc. 8); and indeed a system so unsatisfactory never could and never has taken much root except in minds of a very peculiar and indolent nature. The abnegation of man's proudest faculty, reason, the perpetual indecision on every point, so little accords with the fertile and prodigious activity and creative power of the mind, that the real professors of scepticism have been universally indolent, easy-natured, sensual men, with whom the speculative doubting was stimulus enough. Morhoff ('Polyhistor,' ii., lib. i., c. 6, and l. ii., c. ix.) gives an account of all the sceptical writers in his dull laborious way; Brucker and Endfield ('Hist. of Philos.,' i., b. ii. c. 16) give a more detailed account of their tenets. [PYRRHO, in BIOG. DIV.]

Of modern scepticism it is remarkable, that it differs little from the ancient, and that whatever strides philosophy may have taken in other departments, it has made little or none in that of doubt. The same clenching subtle arguments occurred to a Theætetus as to a Hume. However we will proceed to give a brief historical account of the attempts made to revive it.

Sanchez, a Portuguese physician, published in 1581 a treatise entitled 'De multum nobili et primá universali Scientiâ quod nihil scitur' (on the excellent and first universal science that nothing is known), a rare and extraordinary work, containing the leading arguments of the sceptics propounded in an extravagant manner; but after many sweeping assertions on the impossibility of all science, he at last admits the possibility of truth, and hints very plainly that he himself has attained it. It is an evidence of the restless spirit of the times and the growing servility to the authority of Aristotle and his followers. But nothwithstanding his natural confidence in his own exclusive perception of truth, Sanchez was a real sceptic. Jerom Hernhaym, an abbot of Prague, on the other hand, who wrote a work De Typho Generis Humani' (on the vain glory of human nature), in which he endeavours to expose the falsehood, presumption, and uncertainty of human science, is to be distinguished from Sanchez and the Pyrrhonists; he was a pseudo-sceptic, and his evident design was to depreciate human learning as inimical to divine wisdom, and to lead men wholly to rely upon religious faith.

Of a similar tendency is the celebrated work of Bishop Huet ('Essai sur la Faiblesse de l'Esprit humain'), in which, after exhibiting the principal points of the sceptic philosophy as given in Sextus Empiricus to prove the insufficiency of human knowledge, he falls back upon the consequent necessity of retiring within faith and being content with it. So palpable is the pretence of his scepticism, that besides being a devout and learned bishop, he was the author of 'Demonstratio Evangelica.' Yet with singular inconsistency he addressed this demonstration to the very understanding which he had so triumphantly asserted could *not* attain truth.

Bayle is, as Cousin remarks, the ideal of sceptics. [BAYLE, in BIOG. DIV.]

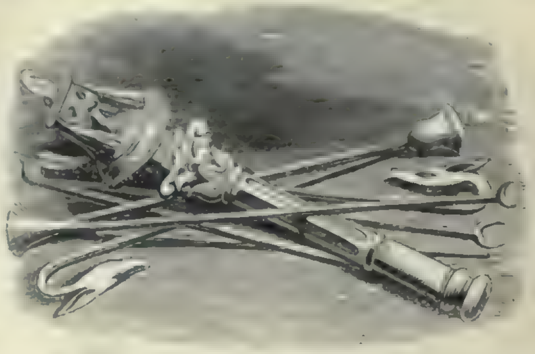
Glanvill, whose 'Scepsis Scientifica, or Confest Ignorance the way to Science,' "has hardly," says Hallam, "been seen by six living persons" (Hallam, 'Lit. of Europe,' iv.), is the systematic sceptic of the 17th century, and his work is altogether a curiosity from the rarity of its notice, the extraordinary nature of its contents, and from its author having been a clergyman and member of the Royal Society, and from his having one year afterwards published a book in favour of witchcraft. [GLANVILL, JOSEPH, in BIOG. DIV.]

Bishop Berkeley, so commonly classed with the philosophical sceptics upon that misconception of the term we have before adverted to, is to be regarded simply as a believer in another system of philosophy from that usually accepted. He denied the existence of an external world. [BERKELEY, in BIOG. DIV.]

Hume was the greatest and the legitimate sceptic of the 18th century. His was genuine Pyrrhonism. He attacked the very foundations of our knowledge by contrasting with them their self-contradictions. "The truth is," observes Dugald Stewart, "that whereas Berkeley was sincerely and *bonâ fide* an idealist, Hume's leading object was plainly to inculcate *universal scepticism.*" ('Essays,' ii., c. 1.) Hume accepted Berkeley's arguments in disproof of external reality, but he went still farther; after denying a *substantive world* (consciousness being concerned only with ideas or representations), he denied on the same ground a *substantive mind*. For, he asks, as we know but impressions and ideas, how can we know that there is anything *more* than these? These are the substance and limit of our knowledge. The mind itself has no distinct, energetic, *substantive* existence—it is but a *succession of ideas.* This is the doctrine expounded by Theætetus the Sophist, in Plato: "there can be nothing true, nothing existent, distinct from the mind's own perceptions" (*τὰ φαινόμενα ἑκάστῳ ταῦτα καὶ εἶναι*). In truth the assumption of an external reality upon any grounds hitherto proposed is gratuitous and questionable. In the fact of perception it is assumed that there is—1, the consciousness; and, 2, the exciting external cause. But upon a patient and rigid interrogation of consciousness, all we find in it, as a fact, is a change in our state of being; beyond this no other element is *given*, but *assumed.* Now the question can never be—whether we *are* conscious of a change of being (since change is the condition of consciousness, and the individual consciousness is proof of itself), but whether, as the sceptic requires to know, we have or can have any *knowledge* or *consciousness* of this external exciting cause in itself. This we must give up. It being admitted that we are influenced by externals mediately (that is, in *representation*), therefore our consciousness is of the *ideas,* not of the *objects themselves.* All that we really know is our own consciousness—our change of being—but we remain ignorant whether that change proceed from an *evolution of being itself*, or from the correlation of being and an external object. The reasonings of Reid, Stewart, Brown, &c. against this doctrine are most puerile. Stewart alone seems to have comprehended it in some of its aspects, but he nowhere fairly exposes and refutes it. If Hume is to be refuted, it must be, as Kant plainly saw, by a reconsideration of the very elements of perception, and an investigation of the received doctrines which Hume, assuming as established, employed as first principles. This was the work of Kant.

Comte, though he calls his system positivisme [COMTE, in BIOG. DIV.] may be considered a sceptic in its modern sense. Nothing, according to him, can be believed that cannot be proved; so he discards all that is accepted as revealed as wholly unestablished, and nothing but the positive facts of physical science are admitted. His own notions of a new religion require a far greater amount of belief than the system he attempts to discredit.

SCEPTRE, from the Greek *skeptron* (*σκῆπτρον*), a staff, or rod carried by princes as the ensign of judicial and sovereign power: whence in the Old Testament (Numbers xvii. 2), and in Homer the most solemn oaths are sworn by it. In the Persepolitan sculptures the sceptre figures as a long walking staff, and in the sculpture found at Nineveh by Botta and Layard, the great king is sometimes represented carrying a similar long staff; but the sceptres borne by the royal sceptre-bearers (and Xenophon mentions that Cyrus was always attended by 300 sceptre-bearers), are shorter and more ornamented. Among the Egyptians sceptres were also much ornamented; of their appearance the following group will give a notion.



The reader who desires to know the different forms in which the sceptre is represented upon ancient coins, may consult Rasche's 'Lexicon Rei Nummariæ,' v. 'Sceptrum.' Le Gendre tells us ('Nouvelle Histoire de France,' 8vo, Paris, 1719, tom. ii., p. 116) that with the kings of France of the first race the sceptre was a golden rod as tall as the king himself. The sceptre, as an ensign of royalty, is of greater antiquity than the crown.

SCHEELE'S GREEN. [COPPER.]

SHILLING. [MONEY.]

SCHISM, SCHISMATICS. The Greek word *schism* (*σχίσμα*) is used several times in the New Testament in its literal sense of a rent or rupture *in one and the same object* (Matt., ix. 16; xxvii. 51; Mark, i. 10; ii. 21; Luke, v. 36; xxiii. 45; John, xix. 24; xxi. 11); and also in a figurative sense for a division of opinion among a number of persons considered collectively as constituting a whole (John, vii. 43; ix. 16; x. 19; Acts, xiv. 4; xxiii. 7). In reference to the Christian church, *schism*, in the abstract sense, is never mentioned. *Schisms* are spoken of twice only (1 Cor., i. 10; xi. 18); and in a third passage, where the union of the members of the church is compared to that of the parts of the human body, the object of this union is stated to be, "that there should be no *schism* in the body." (1 Cor., xii. 24-26.) From a comparison of these passages, it clearly appears that *a schism*, in the New Testament sense, does not imply the open separation which exists between Christians and unbelievers, nor that between the members of different Christian communions, but it denotes something existing within one and the same church; and further, it does not appear to designate any difference of opinion respecting doctrines or ceremonies or forms of government, but rather to refer to a state of mind, to the absence of a spirit of united Christian love. ('Dissent not Schism,' a discourse by T. Binney.)

The common use of the word in ecclesiastical writers is different from this. With them *schism* is nearly synonymous with *separation*; but in its stricter use schism is a separation from the communion of a church on the part of certain of its members who do not differ from its other members on any point of religious doctrine. *Heresy* consists in a dissent from the *doctrines* of a church; *schism* is a dissent from its *government*. From this definition it clearly appears that any attempt to enumerate the schisms of the Christian church would be fruitless, since every community is considered schismatical by all the rest.

The event which ecclesiastical historians call *the great Schism of the West* occurred in the 14th and 15th centuries. After the death of Gregory XI. (A.D. 1378), the cardinals, being compelled by the clamour of the people of Rome to elect an Italian to the popedom, chose Urban VI.; but afterwards the leading members of the college retired to Fondi in Naples, and elected Clement VII., who set up his court at Avignon, while Urban remained at Rome. Clement was recognised as pope by France, Spain, Scotland, Sicily, and Cyprus, and Urban by the rest of Europe. This schism continued till the year 1417, when it was healed by the Council of Constance, which elected Martin V. to the papacy. (Mosheim's 'Ecclesiastical History,' cent. xiv., pt. ii., c. ii., sect. 15, &c.; Waddington's 'Church History,' c. xxiii.)

The other great schism is that between the Greek and Latin churches. [GREEK CHURCH.]

SCHISMA (from *σχίσμα, cleft, division*), an interval, used only in mathematico-musical calculations, equal to half a comma. [COMMA.]

SCHLIPPE'S SALT. The sulphantimoniate of sulphide of sodium. [ANTIMONY. *Pentasulphide of Antimony.*]

SCHOLIUM, *Σχόλιον* (Mathematics), a name given in the older mathematical writers to the remarks which follow a proposition. A scholium must be distinguished from a corollary, inasmuch as the latter necessarily contains some deduction from the demonstration which precedes, which is not the case with the former. A scholium is an appendix containing general remarks upon the scope of a proposition, its application, or its history: everything, in short, which is not an absolute corollary. The word is used by Cicero ('Ep. ad. Att.,' xvi. 7) in its general sense of remark, commentary, or explanation.

SCHOOLS. The true *Theory of Education* can only be developed by considering what the being is on whom it is designed to operate. Education is, according to its etymology, the leading out or unfolding of the human powers. It is obviously therefore a means for a certain purpose. To learn what that purpose is we must refer to experience, and we must investigate the capacities of the human being. These being ascertained, it follows that education is, in any particular case, an instrument for developing them. Now we know that man has not only physical and intellectual, but also moral and spiritual faculties, all of which education ought to take under its care. That education is incomplete which neglects any one of these faculties; and that education discharges its functions imperfectly which does not cultivate the faculties in such degree that their action may be well adjusted, and their general working be harmonious. But if there appear to be any one of the faculties apart from whose influence the rest work indifferently or produce baneful results, and which is found when in healthful vigour to strengthen, refine, and control the whole nature, this power ought to receive primary and chief attention. The work then of education is to foster, strengthen, and raise the physical, intellectual, moral, and spiritual capabilities of man. Some important deductions flow from these principles. Education ought to be universal both in relation to each individual and the community at large; for it ought to be co-extensive with the capabilities on which it is intended to act. It is contrary to the constitution of man and to the designs of God for any one of our capacities to remain undeveloped. They err who neglect to educate the body, and they also who neglect to educate the mind. These errors represent two different classes of men. A certain school of philosophy at least makes light of religious education; physical education has been lamentably neglected by the recognised teachers of religion. The latter error is now disappearing, but the former has been gaining ground; and this error is the more to be deplored because its consequences must be serious and lasting. If any one, certainly the religious faculty may be considered as the moving power of the human being. Religion indeed rightly understood is the central science, round which all other branches of knowledge and all other pure influences are grouped, towards which they gravitate, and from which they receive their light, their heat, and their highest value. But for the peculiar political circumstances of England, any system of popular education which omitted direct religious culture would probably have been considered by thinking men as defective.

There is in truth no other way than that which is afforded by a religious training for forming such a character as the trials and duties of life require both among the rich and the poor. The mere communication of knowledge, and even habits of reflection and inquiry, can do very little towards real happiness. What the people want is true wisdom and moral power, without which life is a scene of conflict and misery; but wisdom and moral power are the peculiar gifts of religion.

Morality therefore should be taught in the schools in connection with the sanctions of religion. Apart from religious influence morality may direct but cannot control. Morality may enlighten and it may enjoin, but of itself it is powerless to govern; it is preceptive, not impulsive, pointing out our path, but not urging us on to pursue it. Now it is power rather than knowledge that man wants; and all genuine power for moral purposes has its source in religion. It may be well to remember that these distinctions of morality and religion are factitious and arbitrary; they are not recognised in the records of the Christian revelation; they find no authority in the human mind. Religion includes morality, or rather, is morality as well as religion, comprising in itself whatever is necessary for man to know, do, and be, whether in this state or the next, in order to fulfil the divine will, to perfect his character, and work out his highest good. Consequently, he that is well trained in the knowledge and practice of the Christian religion has received both a moral and a religious education, and is fitly prepared for the duties of life.

From this it will be seen that the religious education here demanded is not of a dogmatical, much less a sectarian kind; but such instruction as may enlighten the mind of the child and the adult as to their capacities, their duties, and their hopes; and such a discipline as may work the instruction into the character till it "leaven the whole lump."

It is not a little curious that in regard to education we may take a lesson from the ancient Persians,* who, according to Xenophon, removing education from the hands of the parents into the hands of the state, gave the same attention to the moral training of the young as is now under the best circumstances given to their intellectual instruction, and so brought them up under the influence of precept and example, that the state was saved from the painful necessity of inflicting punishment, in consequence of having taken such preventive measures as relieved the youth from the desire of what is low and unjust. Morals with them were a practical science, the principles of which were first taught by word of mouth, and then by actual examples and by daily practice.

The morals taught in primary schools should have a regard to personal, domestic, and social duties, or the obligations which an individual owes to his family and to the state. The instruction should consist not of a mere dry detail of precepts, but should appeal to the reason and affections, that it may both develope them and gain such a reception in the breast of the scholar as to become the living power which governs his conduct.

The preceding remarks lead also to the conclusion that the culture which ensues from education is in itself an end, if indeed it is not the primary and great end of education. The husbandman sows the seed in order to produce grain; the educator disciplines the faculties that he may bring them into vigorous, healthful, and pleasurable activity. In both cases there is an adequate end, a result in which the agents may satisfactorily rest. Education can have no higher object than the creation of happiness by means of the formation of character. This is the great object of the Deity himself; and if even the power which education gives is regarded as an instrument, as a means to some outward result, still the pursuit of mental and moral culture as a good in itself, can have no other than a beneficial result. It is important therefore that the purposes for which education is sought should be placed and kept in their proper rank. That which is secondary must not, however good, be thrust into the first place; and above all that must not be altogether lost sight of, which in reality is in itself a most important result, if not the great end of education. The formation of character then, to make (so to speak) true men and women, beings with their faculties complete, and, in consequence, with all their internal sources of happiness, entire, full, and active—this should be an object carefully studied and diligently pursued by the educator. But here even superior minds halt behind the truth, making the chief object of education some extrinsic result—such as, in the case of males, fitness for the duties of their station in life; in the case of females, such as may prepare them to be pleasing wives and useful mothers—aims excellent in themselves, but scarcely entitled to hold the first rank, if for no other reason than this, that an outward accomplishment does not of necessity imply such an inward culture as will ensure health and vigour of character, and that durable and growing happiness which attends on genuine personal excellence.

The real nature of education considered as an instrument may also be gathered from these remarks. If the subject on which education operates is mental and moral in its character, and the effects which it labours to produce and the aims which it ought to pursue, also mental and moral, the instrument must be of a similar kind. Setting aside then so much of it as is designed for a physical result, education is a mental and a moral influence; in other words, it is mind acting on mind; it is a superior acting on an inferior character; it is human thought and human sympathies brought to bear on kindred elements in the bosoms of the young; it is the power of religion living and breathing in one soul, going forth into another, and kindling within that other corresponding vitality. Whence it is obvious that much of what is called education does not deserve the name; that a mechanical routine is not education, nor dexterity of hand, nor skill in shaping certain forms, nor the utterance of articulate sounds. If so, then reading, writing, and arithmetic, how well soever they may be taught, ought not to be dignified with the name, though they may in favourable circumstances contribute something to education.

The tenor of these observations has determined another thing, namely, what ought to be the prevailing spirit and what the discipline of a school. School in reality holds the place of home; home is God's school, but since present modes of life do not permit the parent to give his child a suitable training, he transfers education to the school. The school therefore should approximate as closely as possible to the home. Now in theory the homes of this land are Christian homes; the school in consequence should be a sort of Christian home. Such a union of terms calls up in the mind ideas of gentleness, forbearance, and affection. These then are the moral qualities which ought to prevail in the school. If so, severity and harshness must be banished as incompatible with the objects for which schools are instituted. Nor are they only incompatible, but they are actually preventive and subversive of those objects. The display of every moral quality produces its like in those who habitually witness it; and unless the aim in school-training is to produce a severe, harsh, and unloving character, severity and harshness must be studiously avoided.

So also the intellectual influence employed should be such as is likely to call out and strengthen the mental powers. The chief good of education is not to be looked for in outward results, nor even in the amount of knowledge communicated, but rather in such habits of mind,—power to fix the thoughts on any given object, to comprehend many particulars at one view, to resolve a complex subject into its component elements, to endure lengthened exertion, to carry determinations into practice, to find resources for thinking and for happiness within—as may fit a young person for discharging his duty under all circumstances. Mere instruction therefore is not education, but simply an instrument of education. The aim should be so to inform the mind, as by the very act of informing to develope and strengthen its powers. The instruction then that deadens the appetite for knowledge and overloads the powers is not education, but something foreign to its nature.

There are two modes, corresponding with two processes, by which the mind carries on its own education, namely, synthesis and analysis, which should be studied and employed by the educator as his great instruments. By synthesis he will, both orally and by means of manuals, offer knowledge to the mind in a simple, attractive, yet systematic form, rising by degrees from the more to the less easy, and from the simple to the complex. By analysis he will lead the child to decompose the matter of instruction which he has received, to trace out the relations of the several portions to one or more elementary principles, their connections with other branches of knowledge, and the more obvious deductions which may be made from them. Thus will he at once ascertain that he has succeeded in communicating his lessons to the pupil, and in making those lessons themselves prolific in additional information.

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* Not that we suppose Xenophon represents a real state of society; but the opinions are just as valuable as if he did.

In the employment of these instruments the educator must be careful to follow nature in her order of unfolding the faculties; he must address those first which appear first, and he must carefully abstain from anything calculated to force any natural power into premature activity, or to overwork any faculty when it has come forth. Now the sight, the hearing, and the touch are the gifts of nature which are earliest developed. The power of reflection comes at a later period, and only as a result of the operation and influence of the senses. The mind of a child is an empty storehouse; the eye, the ear, and the touch are the portals through which this storehouse is supplied with matter, which, received and laid up, is afterwards operated upon by the mind, pursuant to its own laws. If then the senses are the first of our faculties which are fit for use, the senses should receive the earliest attention of the educator. A child can immediately observe; therefore the power of observation should be first cultivated. It is important that all the senses should receive cultivation, not merely for the information of which they may be made the vehicle, but also with a view to that training which is first among the purposes of education; but the eye may take some precedence, as the sense of sight comes first in the order of natural sensibility. At a very early period the educator should begin to teach his scholar how to use his eyes and other senses, both by words and by examples; and as the other faculties are found to expand themselves, so should they be from the first taken under his fostering care, that by exercise he may bring them to act harmoniously and efficiently.

It is, however, necessary that education should be also regarded as a means to some outward result, and here at once the social distinctions of life present themselves to our attention and modify our views. It is obvious that a child should learn that which will best prepare him for the labours, the trials, and the duties through which he will have to pass. In other words, the children of the poor ought to be taught what most concerns them to know, what they will have immediately to do, and what, other things remaining the same, will prove the most fruitful source of happiness. At the same time, the primary object of education—the formation of character—should also be kept in view; and the discipline through which a child ought to be conducted and the subjects of knowledge to be placed before him, must be determined by a joint reference to his capacities and his probable future station in life.

Now in treating of the mere external parts of education, health of the body is the first thing that demands our attention. The body is the instrument by which the mind executes its purposes, and by which therefore much of the good which education does makes itself felt. It would consequently seem to be of the first importance that this instrument should be kept in the highest state of efficiency. But this is an end which cannot be attained if men are brought up in total ignorance of the structure of their bodies, and of the laws of health. From the first, therefore, children should be habitually taught to know the conditions on which health depends; such as relate to the state of their dwellings, the condition of their persons as to cleanliness and other matters of the like kind, of which not only the labouring classes but many others are extremely ignorant. There is no peculiar difficulty in communicating the requisite knowledge, and on the part of the young the reception of it would be easy and pleasant. If we measure knowledge by its real usefulness, that is, its power to promote happiness, what comparison is there between this information and a knowledge of geography, history, or other things of the kind? A man may be ignorant of all these matters, and yet live a virtuous, happy, and long life, but he cannot with impunity remain ignorant of the laws of health. The most absurd and the most injurious prejudices prevail on this point among the people; and in general they imagine that sickness, disease, and death depend on causes altogether beyond their reach, on luck or chance, and that they have no other resource than passive submission.

It is also by means of the body that the children of the poor will have to get their bread. They should be taught to know this as a fact, as a simple piece of information, which involves neither merit nor demerit, neither honour nor dishonour. For such exercises of the body as they are likely to be called to, they ought from an early period to be prepared while at school by an industrial training.

This remark comprises much more than a demand of bodily labour from the young. It involves such a course of instruction as may best prepare them for their future occupations. There is no pursuit in life—not even that which is most mechanical—which does not depend on, or is not connected with, certain principles; for all manual labour is only the carrying out and realisation of results for which science has prepared the way. It is equally certain that there is no labour which may not be lightened or relieved by knowledge. A good education therefore would make the labourer acquainted with the facts and principles on which his art is built and thus enable him to enjoy the rational and sustaining pleasure of working understandingly, with a view to a given result, and labouring therefore in a manner fitted to improve his character as a man as well as his efficiency as a workman.

But no improvement can be expected in popular education until a better race of teachers is provided. Great as is the deficiency of schools, yet if they were filled with competent instructors, the chief evil would be remedied.

In the houses too of the working classes, particularly in the manufacturing districts, a change is most desirable. Whatever time may be occupied in school duties, there are many hours which a child spends during which the educator has no influence over him; and these are the very times at which the young are most susceptible of impressions; when the moral and intellectual capacities open to surrounding influences, and receive them readily and retain the impression deeply. In the actual state of things then, the real educators of the young are their parents, their brothers and sisters, their playmates, their casual companions—in one word, their home. No small part of these evils results from the employment of females in mills and factories. In the ordinary state of society all that should be peculiar in a female's education would be left to her mother. But among a large part of the manufacturing classes there are not mothers who could give anything approaching to the requisite education. There is then no other resource but the school. It is altogether impossible that the labouring classes, at least of the manufacturing districts, can ever be happy until a new and improved race of mothers appears. In addition, therefore, to the educational requisites already mentioned, it is necessary that there should be a sufficient number of girls' schools in which the ordinary arts of domestic life—baking, cooking, sewing, knitting, making and mending, should be taught. This matter is of vital interest to the working man, and therefore to the country, for it matters little what the labourer's earnings are, what his own intelligence is, if he has not a thrifty, kind-hearted, sensible, and industrious wife.

Among the changes desirable on the part of the parents is the existence of a disposition to provide out of their own resources suitable means for the education of their children. That it is their duty to make this provision when they have the power is unquestionable; and although it is too much to expect at the present, yet something may be done towards it, and the complete fulfilment of the claim may be looked to as an ultimate end. There is nothing but their own exertions which can bring to the labouring classes all the good which education can convey. The charity of education, like charity of every kind, tends to pauperise those whom it aims to benefit: and so long as the education of the poor depends on the efforts of rival and conflicting parties in religion or in politics, it is impossible that the power thus gained should not be used in order to further the opinions and interests of the several parties. In the meantime the people are regarded and treated as instruments for a purpose, and their education is shaped and varied not by a regard to what is absolutely best, but to what is conducive to the ends of the party which directs it. It is true that some good has resulted from the efforts of individuals and societies by which such education as the poor have received has been conducted during a century. It is equally true that these voluntary exertions have in many cases sprung from pure and enlarged benevolence. Still they could not under the circumstances fail to be accompanied by a large amount of sectarian and party feeling. At the present hour this is peculiarly the case. The church is arrayed against dissent, dissent is arrayed against the church, in competition for the largest share in the education of the children of the poor; and the rivalry is in greater or less activity through every city and village of the kingdom.

The magnitude of the evil and of the interests which are at stake seem to demand the intervention of the government by means of a general catholic and truly national education. But the conflict of parties gives little reason to expect this at present. Still the government is doing something; but the remedial measures employed cannot overtake the disorder. Perhaps after all, the end to be aimed at is, that the people should seriously take the education of their children into their own hands, or intrust it to proper persons of their own choice. This end may be facilitated by that love of independence which has hitherto been a marked feature in the character of Englishmen, who do not like either a government or individuals to be obtruding on their private concerns. Assuming, then, that the importance of education for all classes is now generally admitted, we proceed to notice our grammar and primary schools, and the laws which affect them.

Endowed Schools. An endowed school in England is a school which was established and is supported by funds given and appropriated to the perpetual use of such school, either by the sovereign or by private individuals. The endowment provides salaries for the master and usher, if there be one, and gratuitous instruction to pupils, either generally or the children of persons who live within certain defined limits. Endowed schools may be divided, with respect to the objects of the founder, into grammar-schools, and schools not grammar-schools. A grammar-school is generally defined to be a school in which the learned languages, the Latin and the Greek, are taught. Endowed schools may also be divided, with respect to their constitution for the purposes of government, into schools incorporated and schools not incorporated. Incorporated schools belong to the class of corporations called eleemosynary, which comprehends colleges and halls, and chartered hospitals or alms-houses. [COLLEGE.]

Endowed schools are comprehended under the general legal name of Charities, as that word is used in the act of the 43rd of Elizabeth, chap. 4, which is entitled "An Act to redress the Misemployment of Lands, Goods, and Stocks of Money heretofore given to Charitable Uses." Incorporated schools have generally been founded by the authority of letters patent from the crown, but in some cases by act of parliament. The usual course of proceeding has been for the person who intended to give property for the foundation of a school, to apply to the crown for a licence. The licence is given in the form of letters patent, which empower the person to found such a school, and to make, or to empower others to make, rules and regulations for its government, provided they are not at variance with the terms of the patent. The patent also incorporates certain persons and their successors, who are named or referred to in it, as the governors of the school. This was the form of foundation in the case of Harrow School, which was founded by John Lyon, in the 14th year of Elizabeth, pursuant to letters patent from the queen. Sometimes the master and usher are made members of the corporation, or the master only; and in the instance of Berkhampstead School, which was founded by act of parliament (2 & 3 Edw. VI., reciting certain letters patent of Henry VIII.), the corporation consists of the master and usher only, of whom the master is appointed by the crown, and the usher is appointed by the master. Lands and other property of such a school are vested in the corporation, whose duty it is to apply them, pursuant to the terms of the donation, in supporting the school. Many school endowments are of a mixed nature, the funds being appropriated both to the support of a free-school and for other charitable purposes. These other purposes are very various; but among them the union or connection of a hospital or alms-house with a free-school is one of the most common.

Where there is no charter of incorporation, which is the case in a great number of school endowments, the lands and other property of the school are vested in trustees, whose duties, as to the application of the funds, are the same as in the case of an incorporated school. It is necessary from time to time for the actual trustees to add to their numbers by such legal modes of conveyance as shall vest the school property in them and the new trustees jointly. These conveyances sometimes cause a considerable expense; and when they have been neglected, and the estates have consequently become vested in the heir-at-law of the surviving trustee, some difficulty is occasionally experienced in finding out the person in whom the school estates have thus become vested. When the school property consists of money, the same kind of difficulty arises; and money is also more liable to be lost than land.

Every charity, and schools amongst the rest, seems to be subject to visitation. We shall first speak of incorporated schools.

The founder may make the persons to whom he gives the school property on trust also the governors of his foundation for all purposes; and if he names no special visitor, it appears that such persons will be visitors as well as trustees. If he names a person as visitor, such person is called a special visitor; and it is a general rule that if the founder names no special visitor, and does not constitute the governors of his foundation the visitors, the heir-at-law of the founder will be visitor; and if there is no heir-at-law, the crown will visit by the lord keeper of the great seal. The king is visitor of all schools founded by himself or his ancestors. The duties of trustees and visitors are quite distinct, whether the same persons are trustees and visitors, or the trustees and visitors are different. It is the duty of trustees to preserve the school property, and to apply it to the purposes intended by the founder. In respect of their trust, trustees are subject to the jurisdiction of the Court of Chancery, like all other trustees; and of course they are answerable for all misapplication of the funds. It is the visitor's duty to inquire into the behaviour of the master and usher in their respective offices, and into the general conduct of the school. He must judge according to the founder's rules, which he cannot alter unless he is empowered by the terms of the donation to do so. There seems to be no reason for supposing that the king, in respect of royal foundations, has any further power than other persons, and consequently he cannot alter the terms of the donation, unless this power was originally reserved to the founder and his successors; but on this matter there may be some difference of opinion. The visitor, or those who have visitorial power, can alone remove a master or usher of an endowed school. The Court of Chancery never removes a master or usher, when they are part of the corporate body, on the general principle that this court has no power to remove a corporator of any kind; and when there is a visitor, or persons with visitorial power, the court never attempts directly to remove a master or usher, even if they are not members of the corporation. (17 Ves., Att.-Gen. *v.* the Earl of Clarendon.)

Trustees of endowed schools which are not incorporated are accountable in a court of equity for the management of the school property. But the internal management of the school still belongs to the special visitor, if there is one; and if there is no special visitor it belongs to the founder's heir. Trustees of endowed schools, simply as such, are merely the guardians of the property, as already observed; and it is their duty to take care of it, and to apply the income according to the founder's intention. It has, however, happened that in schools not incorporated the jurisdiction of the Court of Chancery and the visitorial jurisdiction have not been kept quite distinct; and cases have arisen in which it has been found difficult to determine what ought to be the proper mode of proceeding.

A free grammar-school was an endowment for teaching the learned languages, or Greek and Latin, and for no other purpose, unless the founder has prescribed other things to be taught besides grammar. This legal meaning of the term grammar-school has been fixed by various judicial decisions, and it appears to be established that, if the founder merely expresses his intention to found a grammar-school, the school must be a school for teaching Latin and Greek only, at least, so far as the teaching is gratuitous; other branches of instruction may be introduced, but the scholars must pay for this extra instruction.

Grammar-schools have now for a long time been solely regulated by the Court of Chancery, which, though affecting merely to deal with them in respect of the trusts and the application of the trust-monies, has in fact gone much farther. The court may be applied to for the purpose of establishing a school where funds have been given for the purpose, but the object cannot be effected without the aid of the court. It may also be applied to for the purpose of correcting a misapplication of the funds. The court may also be applied to in order to sanction the application of the school funds when they have increased beyond the amount required for the purposes indicated by the founder. Such surplus funds are often applied in establishing exhibitions or annual allowances to be paid to meritorious boys who have been educated at the school, during their residence at college. The master's scheme for the regulation of Tunbridge school, in Kent, which was confirmed by the Court of Chancery, established sixteen exhibitions of 100*l.* each, which are tenable at any college of Oxford or Cambridge, and payable out of the founder's endowment. It also extended the benefits of the school beyond the limits fixed by the founder, and made various other regulations for the improvement of the school, having regard to the then annual rents of the school estates.

The previous remarks on grammar-schools must be taken subject to the provisions contained in a recent Act of Parliament, which is the only attempt that has been made by the legislature to regulate schools of this class. This act (3 & 4 Vict. c. 77) is entitled "An Act for improving the Condition and extending the Benefits of Grammar-Schools." The act recites, among other things, that the "patrons, visitors, and governors of such grammar-schools are generally unable of their own authority to establish any other system of education than is expressly provided for by the foundation, and her majesty's courts of law and equity are frequently unable to give adequate relief, and in no case but at considerable expense." The act then declares that the courts of equity shall have power, as in the act provided, "to make such decrees or orders as to the said courts shall seem expedient, as well for extending the system of education to other useful branches of literature and science, in addition to or (subject to the provisions thereinafter contained) in lieu of the Greek and Latin languages, or such other instruction as may be required by the terms of the foundation or the then existing statutes, as also for extending or restricting the freedom or the right of admission to such school, by determining the number or the qualifications of boys who may thereafter be admissible thereto as free scholars or otherwise, and for settling the terms of admission to and continuance in the same, and to establish such schemes for the application of the revenues of any such schools as may in the opinion of the court be conducive to the rendering or maintaining such schools in the greatest degree efficient and useful, with due regard to the intentions of the respective founders and benefactors, and to declare at what period, and upon what event, such decrees or orders, or any directions contained therein, shall be brought into operation; and that such decrees and orders shall have force and effect, notwithstanding any provisions contained in the instruments of foundation, endowment, or benefaction, or in the then existing statutes;" but it is provided, that if there shall be any special visitor appointed by the founder or other competent authority, he shall be heard on the matters in question before the court makes any orders or decrees.

This enactment extends the power of the court over grammar-schools very considerably, as will appear from what has been said; not so much however, if we view what the court has done, as if we take the declarations of the most eminent equity judges as to what the court can do. The power however of changing a grammar-school into one not a grammar-school, which is given by this act, is a considerable extension of authority; but the power is limited to cases (§ 3) where the necessity of such a change arises from insufficiency of the revenues of a grammar-school for the purpose of such school. But this provision as it has properly been remarked, will be of very difficult application; for in many successful grammar-schools the revenue is small, and in some which are not successful it is large. Smallness of revenue, therefore, will not of itself prove "insufficiency of revenues" in the sense intended by the act. The same section contains also a provision, that except in this case of insufficient revenues, the court shall not by this act be authorised to dispense with any statute or provision now existing, so far as relates to the qualification of any schoolmaster or under-master. The dispensing power then which the court has often assumed, as shown in some instances above mentioned, remains as it was; that is, it does not exist at all.

When a grammar-school shall have been made into another kind of school under the provisions of this act, it is still to be considered a grammar-school, and subject to the jurisdiction of the ordinary as heretofore.

In case there shall be in any city, town, or place, any grammar-school or grammar-schools with insufficient revenues, they may be united, with the consent of the visitor, patron, and governor of every school to be affected thereby. The legal meaning of city and town (township) is sufficiently precise, but "place" has no legal meaning, and the framers of the act have forgotten to give it one in their 25th section, which treats of the construction of terms in that act.

The court is also empowered (§ 14) to enlarge the powers of those who have "authority by way of visitation or otherwise in respect of the disclipine of any grammar-school;" and where no authority by way of visitation is vested in any known person, the bishop of the diocese may apply to the Court of Chancery, stating the facts, and the court may, if it so think fit, give the bishop liberty to visit and regulate the said school in respect of the discipline, but not otherwise. This provision, for various reasons, will prove completely inoperative.

The act gives a summary remedy against masters who hold the premises of any grammar-school after dismissal, or after ceasing to be masters. Such masters are to be turned out in like manner as is provided in the case of other persons holding over, by the Act of the 1 & 2 Vict., entitled "An Act to facilitate the Recovery of Possession of Tenements after due Determination of the Tenancy."

All applications to the court under this act may be (not *must*) made by petition only, and such petitions are to be presented, heard, and determined according to the provisions of the 52 Geo. III. c. 101.

The act saves the rights of the ordinary. It is also declared not to extend "to the universities of Oxford or Cambridge, or to any college or hall within the same, or to the university of London, or to any colleges connected therewith, or to the university of Durham, or to the colleges of St. David's or St. Bees, or the grammar-schools of Westminster, Eton, Winchester, Harrow, Charter-House, Rugby, Merchant Tailors', St. Paul's, Christ's Hospital, Birmingham, Manchester, or Macclesfield, or Lowth, or such schools as form part of any cathedral or collegiate church." But the exemption does not extend to the grammar-schools of which the universities of Oxford or Cambridge, or the colleges and halls within the same, are trustees, though these schools were excepted from the Commissioners' inquiry by the 5 & 6 Wm. IV. c. 71.

It appears from the rules of many grammar-schools that religious instruction according to the principles of the Church of England, as established at the Reformation, is a part of the instruction which the founder contemplated; and when nothing is said about religious instruction, it is probable that it was always the practice to give such instruction in grammar-schools. That it was part of the discipline of such schools before the Reformation cannot be doubted, and there is no reason why it should have ceased to be so after the Reformation, as will presently appear. It is generally asserted that in every grammar-school religious instruction ought to be given, and according to the tenets of the Church of England; and that no person can undertake the office of schoolmaster in a grammar-school without the licence of the ordinary. This latter question was argued in the case of Rex *v.* the Archbishop of York. (6 'T. R.,' 490.) A mandamus was directed to the archbishop directing him to license R. W. to teach in the grammar-school at Skipton, in the county of York. The return of the archbishop was that the licensing of schoolmasters belongs to the archbishops and bishops of England; that R. W. had refused to be examined; and he relied as well on the ancient canon law as upon the canons confirmed in 1603 by James I. ('The Constitutions and Canons Ecclesiastical,' "Schoolmaster," 77, 78, 79.) The return was allowed; and consequently it was determined that the ordinary has power to license all schoolmasters, and not merely masters of grammar-schools. As to schoolmasters generally, the practice is discontinued, and probably it is not always observed in the case of masters of grammar-schools.

From the terms of this licence it appears that the master of every school who is licensed by the ordinary must be a member of the Church of England, and must take the oath and make the subscriptions and declarations which are recited in the licence.

It is a common notion that the master of a grammar-school must be a graduate of Oxford or Cambridge, and in holy orders, and such is the present practice; but it is by no means always the case that the rules of endowed schools require the master to be in holy orders. The founders seem generally to have considered this a matter of indifference; but many of them provided that if the master was in orders, or took orders, he should not at least encumber himself with the cure of souls. The principle clearly was, that the master of a grammar-school should devote himself solely to that work; and it was a good principle. The Court of Chancery has in various cases ordered that the master should be a clergyman, where the founder has not so ordered. Dean Colet, the founder of St. Paul's School, London, ordered by his statutes that neither of the masters of that school, if in orders, nor the chaplain, shall have any benefice with cure or service which may hinder the business of the school. He appointed a chaplain to the school, thereby appearing to intend that the religious instruction should not be given by the masters of grammar, who would be fully employed otherwise.

It has sometimes been doubted whether a master of a grammar-school could hold ecclesiastical preferment with it. If the founder has not forbidden this, there is no rule of law which prevents him. If the holding of the two offices should cause him to neglect the duties of either, the remedy is just the same as if he neglected either of his offices for any other cause.

Many grammar-schools are only free to the children of a particular parish, or of some particular parishes; but this privilege has occasionally been extended to a greater surface, as in the case of Tunbridge school. Some are free to all persons, which is the case with some of King Edward VI.'s endowments. Sometimes the number of free boys is limited, but the master is allowed to take pay scholars, either by usage or by the founder's rules. At present the practice is for masters of grammar-schools to take boarders if they choose, but in some cases the number is limited. Abuses undoubtedly have arisen from the practice of the master taking boarders, and the children of the parish or township for which the school was intended have been neglected or led to quit the school sometimes in consequence of the head master being solely intent on having a profitable boarding school. But in most cases the school has benefited by the master taking boarders; and this has frequently been the only means by which the school has been able to maintain itself as a grammar-school. When the situation has been a good one, an able master has often been found willing to take a grammar-school with a house, and a small salary attached to it, in the hope of making up a competent income by boarders. As this can only be effected by the master's care and diligence in teaching, a small neighbourhood has thus frequently enjoyed the advantage of its grammar-school, which otherwise would have been lost.

Endowments for education are probably nearly as old as endowments for the support of the church. Before the Reformation there were schools connected with many religious foundations, and there were also many private endowments for education. Perhaps one of the oldest schools of which anything is known is the school of Canterbury. Theodore, who was consecrated archbishop of Canterbury in 668 (according to some authorities), founded a school or college by licence from the pope. This school certainly existed for a long time; and there is a record of a suit before the Archbishop of Canterbury in 1321, between the rector of the grammar-schools of the city (supposed to be Theodore's school or its representative) and the rector of St. Martin's, who kept a school in right of the church. The object of the suit was to limit the rector of St. Martin's in the number of his scholars. This school probably existed till the Reformation, at least this is the time when the present King's school at Canterbury was established by Henry VIII., and probably on the ruins of the old school. Before the Reformation schools were also connected with chantries, and it was the duty of the priest to teach the children grammar and singing. There are still various indications of this connection between schools and religious foundations in the fact that some schools are still, or were till lately, kept in the church, or in a building which was part of it. There are many schools still in existence which were founded before the Reformation, but a very great number were founded immediately after that event, and one professed object of king Edward VI. in dissolving the chantries and other religious foundations then existing was for the purpose of establishing grammar-schools, as appears from the recital of the act for that purpose (1 Ed. VI. c. 14.) [CHANTRY.]

Though the act was much abused, the king did found a considerable number of schools, now commonly called King Edward's Schools, out of tithes that formerly belonged to religious houses or chantry lands; and many of these schools, owing to the improved value of their property, are now among the richest foundations of the kind in England. In these, as in many other grammar-schools, a certain number of persons were incorporated as trustees and governors, and provision was made for a master and usher. At that time the endowments varied in annual value from twenty to thirty and forty pounds per annum.

A large proportion of the grammar-schools were founded in the reigns of Edward VI. and Elizabeth, and there is no doubt that the desire to give complete ascendancy to the tenets of the Reformed Church was a motive which weighed strongly with many of the founders. Since the reign of Elizabeth we find grammar-schools occasionally established, but less frequently, while endowments for schools not grammar-schools have gradually increased so as to be much more numerous than the old schools. Foundations of the latter kind are still made by the bounty of individuals from time to time; and an Act of Parliament (2 & 3 Wm. IV. c. 115) has made it lawful to give money by will for the establishing of Roman Catholic schools. By the 23 Vict., c. 11, passed in 1860, the trustees of grammar-schools in England and Wales are empowered (except those mentioned in the 3 & 4 Vict., c. 77, those in connection with the National Society, those maintained by private subscription, and those where the endowment does not expressly demand conformity to certain religious doctrines) to frame orders for securing the admission of children whose parents are not in communion with the denomination or sect of which the doctrines are taught in the school. The statute of the 9th Geo. II. c. 36, commonly called the Mortmain Act, has placed certain restrictions on gifts by will for *charitable* purposes, which restrictions consequently extend to donations by will for the establishment or support of schools. [Mortmain.]

The history of our grammar-schools before the Reformation would be a large part of the history of education in England, for up to that time there were probably no other schools. From the time of the Reformation, and particularly till within the last half-century, the grammar-schools of England were the chief places of early instruction for all those who received a liberal training. From these often humble and unpretending edifices has issued a series of names illustrious in the annals of their country—a succession of men, often of obscure parentage and stinted means, who have justified the wisdom of the founders of grammar-schools in providing education for those who would otherwise have been without it, and thus securing to the state the services of the best of her children. Though circumstances are now greatly changed, there is nothing in the present condition of the country which renders it prudent to alter the foundation of these schools to any great extent; and certainly there is every reason for supporting them in all the integrity of their revenues, and for labouring to make them as efficient as their means will allow.

The voluminous Reports of the Commissioners appointed in 1818 and 1837 to inquire into Charities, contain the most complete accessible information on the several schools which were visited by the commissioners. But this vast mass of materials is only useful for those who wish to inquire into some particular endowment, or for the few who have leisure to study the Reports and the knowledge necessary to enable them to make a right use of them. The number of grammar-schools reported on by the commissioners is 700; the number of endowed schools not classical, 2150; and of charities for education not attached to endowed schools, 3390. The income of grammar-schools reported on was 152,047*l.* 14*s.* 1*d.*; of endowed schools (not classical), 141,385*l.* 2*s.* 6*d.*; and of the other charities given for or applied to education, 19,112*l.* 8*s.* 8*d.*

Primary Schools. The education supplied by primary schools may be considered as embracing not only that of young children, but that of the children of the poor in general. The consideration of it involves the whole matter of what is generally termed "popular education," comprising the Sunday-school, the Day-school, and the Infant-school.

The theory of the English church establishment supposes that the youth of the country are directly or indirectly under the care of the clergy for the purposes of education; and there was a period in which none but the clergy were engaged in the business of instruction. Various circumstances, however, added to the increase of population, its growth in wealth, the rise of new commercial interests, together with the spread of dissent, caused the people to outgrow the very scanty provision made for their education, so that towards the end of the last century an opinion became prevalent of the urgent necessity both for the extension and the improvement of the means for the education of poor children. The result was the commencement in England of a series of efforts which have led both here and abroad to the most beneficial results.

Raikes of Gloucester is generally considered the founder of Sunday-schools, but other persons preceded him in the benevolent effort to make the Sunday subservient to the education of neglected children. The Rev. Theophilus Lindsey, shortly after he had taken possession of his vicarage of Catterick in Yorkshire, in 1763, employed in this way a portion of each Sunday. Mrs Cappe, wife of the Rev. Newcome Cappe of York, then Miss Harrison, "endeavoured," she observes in her Life, "to imitate at Bedale the example which I so much admired at Catterick." In the year 1769 a Sunday-school was commenced by Miss Ball at High Wycombe, Bucks. She was a lady of great piety, and very earnest in doing good. Her custom was to assemble as many as thirty or forty children on Sunday morning, in order to hear them read the Scriptures and repeat the Catechism and the Collect preparatory to going to church.

The idea of Sunday instruction was communicated to Mr. Raikes by the Rev. Mr. Stock, curate of St. John's, Gloucester. [Raikes, in Biog. Div.]

The "National Schools" took their rise from the impulse given by the exertions of Dr. Andrew Bell. [Bell, Dr. Andrew, in Biog. Div.]

Joseph Lancaster, born in 1771, was a member of the Society of Friends. [Lancaster, Joseph, in Biog. Div.] His efforts resulted in the formation of the British and Foreign School Society.

Infant-schools are designed to prevent evil, and to train young children in the practice of virtue and kind feeling, as well as to the pursuit of knowledge, particularly in those cases in which the parents from their occupation are unable, or from their dispositions are unwilling, to take proper care of their offspring. At present having been found of great service in the humbler ranks of society, they are slowly extending themselves among the middle classes. If the whole of English education were planned with similar foresight and care, and conducted on similar principles, so as to make one connected series from infancy to manhood, extending through all ranks, modified only by the peculiar facilities and destination of each, the highest advantages would follow. The infant-school system makes the school-room into a nursery and a playground, in which virtue, intelligence, and love preside, direct the movements, and regulate and foster the emotions. The scholars are instructed while they play, and learn to associate pleasurable feelings with their school pursuits.

The real founder of Infant-Schools appears to have been the Pastor Oberlin [Oberlin, in Biog. Div.]; but Pestalozzi [Biog. Div.] also aided. Mr. Owen was the first Englishman to establish an infant-school on a large scale, and for definite purposes—and certainly the school which he founded at New Lanark in Scotland at least ranks among the earliest.

In the year 1819 Henry Brougham, the Marquis of Lansdowne, Joseph Wilson, John Smith (who had seen the schools at New Lanark five years previously), and other gentlemen, established, by subscription among themselves, a school in Brewer's Green (now Vincent Square), Tothill Fields, Westminster, on the plan of Mr. Owen's schools at New Lanark; and James Buchanan, an experienced teacher in those schools, came to London, with Mr. Owen's approbation, to superintend the new school.

On the 24th of July, 1820, an infant school was opened in Quaker-Street, Spitalfields, London. This school was established at the sole expense of Joseph Wilson, above mentioned. Samuel Wilderspin and his wife were engaged to manage the school, and their salaries were fixed and paid by Mr. Wilson. Wilderspin had been previously a clerk in a mercantile house in the city. He remained in this situation some years, and published a small work 'On the Importance of educating the Infant Poor from the age of eighteen months to seven years, containing an account of the Spitalfields Infant School, and the new System of Instruction there adopted. By S. Wilderspin, master of the above school. 12mo, 2nd edition, with considerable additions, Lond., 1824.' The first edition was probably published in 1823, but we have no evidence. Mr. Wilderspin was afterwards employed in delivering lectures on infant education, in assisting in the establishment of new schools, and in otherwise promoting the cause of infant education in all parts of Great Britain as well as in London. Mr. Buchanan was master of the Westminster infant school about twenty years, and then went to America.

Of a different class in many respects to either of those yet noticed are the schools called *Birkbeck Schools.* They were established by a private gentleman, Mr. William Ellis [Ellis, William, in Biog. Div.], at his own expense, but are intended to be ultimately maintained by the weekly payments of the children. As is more fully explained in the article referred to (see also the 'Companion to the Almanac,' for 1860, p. 13, &c.), the distinctive feature of the schools is that instruction in *social science* is made a matter of primary importance: it being the opinion of the founder "that the habits of reflection and self-examination, which its study calls forth, cannot fail to impart a useful bias to the character and conduct in after life." Several of these schools are in operation, the principal one, a large and flourishing establishment in which several hundred children are under instruction, is at Peckham.

Reformatory and Ragged Schools have been treated of under those heads.

A "College of Preceptors" has been also established, which examines and gives certificates of competence to persons intending to be teachers. This has tended greatly to improve the teaching in private schools; while the Oxford and Cambridge middle-class examinations of the scholars of any school, as well as the throwing open, to a certain extent, of government situations to public competition, have had considerable influence in raising the character of the instruction given.

Training-schools have also been established in connection with the National Society. Some of the Diocesan Boards of Education appropriate a part of their funds to the erection of school-houses; others assist in increasing the salaries of teachers and improving the routine of schools.

In giving a brief notice of what has been done for the improvement of education in England, the efforts of government claim chief attention. Those efforts have proceeded on the principle of stimulating and expanding the agencies which are already in existence, rather than of supplying the means for establishing a general and uniform system of education, under the control of the state. For several years grants of 20,000*l.* per annum were made by Parliament, and distributed chiefly through the National and the British or Lancasterian schools, in furtherance of education.

These schools increased, and with them the government grants. Schools receiving grants are subject to the inspection of persons appointed by government. In 1859 there was granted by Parliament 836,920*l.* for public education in Great Britain, and 249,468*l.* for Ireland; and in England, in 1858, at the time of inspection there were 821,744 scholars present. In 1860 the grants were 798,167*l.* for Great Britain and 270,722*l.* for Ireland; and in Ireland, on Dec. 31, 1859, there were 519,175 children on the rolls, and an average of 269,203 in daily attendance. Grants are allowed by the Council of Education to all schools admitting of the inspection of the government inspectors. There are 24 training colleges. In almost every Poor-Law Union schools are established for the pauper children, at which, in July, 1859, there were 65,656 children receiving instruction. In Ireland, agricultural schools have been established in connection with the Poor-Law Union, which have proved successful in their pecuniary results and beneficial to the children.

The efforts of the legislature have not been confined to grants of money or to the poor. Without noticing the number of schemes proposed, and the debates upon them, in which the adherents of the voluntary principle, and those advocating a national superintendence and support, have contrived to neutralise each other's efforts, we will shortly notice what has been actually done. In 1842 an act was passed for facilitating the acquisition of sites for school-houses, which was repeated, amended, and extended in 1850, 1852, and 1853. In 1843 land and buildings occupied by societies for literary and scientific purposes were exempted from the payment of county, borough, parochial, and other local rates; and in 1854 further facilities for the institution of such societies were afforded by another act. In 1844, in a Poor-Law Amendment Act, the Poor-Law Commissioners were empowered to combine parishes and unions into school districts, to form boards for their governance, which boards, subject to the regulations of the commissioners, were to appoint, pay, and control its teachers and other officers for the purpose of instructing the children of the poor; but no child was to be compelled to attend any religious service contrary to the principles of, or be instructed in, any religious creed contrary to that professed by. the parents; and in 1848 the provisions of the act were amended, by extending them to parishes not in unions, and removing the limitation of expense, previously limited to one-fifth of the aggregate of the poor-law expenditure. The 18 Vict. c. 34, 1855, gives guardians of poor-law unions power to afford relief, so as to enable poor children, between the ages of four and sixteen, to be sent to schools. In 1847 the law regulating the attendance at school of children employed in print-works was amended. In 1850 an act was passed empowering town-councils to establish public libraries and museums, by imposing a small rate, such libraries and museums to be open to the public free of expense; extended in 1855 to places not having councils and to parishes; and similar acts were passed for Scotland and Ireland in 1853, 1854, and 1855.

In addition to this legislative action, the general public have not been wanting in efforts to diffuse education. In most of the large towns ragged schools have been formed and supported for the instruction of the more destitute children; and, in conjunction with mere school learning, it has been endeavoured to inculcate habits of industry, by establishing shoe-black brigades and crossing sweepers, by which boys during the day are enabled to earn money, a part being devoted to their support, and the remainder placed to their account, to form a fund for their future advancement, their evenings being spent in school. The results, on the whole, have been very satisfactory. Schools have also been established for teaching girls common things, chiefly in domestic economy. The preparation of teachers has been also more attended to, and few of the paid instructors, either male or female, are now appointed to any of the schools without certificates of capability from recognised examiners. For this purpose the National Society, the British and Foreign School Society, the Congregational Board of Education, and the Voluntary School Society, have established normal and model schools, where instruction is afforded, capability tested, and certificates granted. Inspectors are appointed to visit all the schools by the Board of Education, and also by the above-named societies to visit their own.

In 1845 an act was passed for endowing Maynooth College for the better education of the Roman Catholic priesthood. In the same year was also passed an act "enabling her Majesty to endow new Colleges," in consequence of which the Queen's Colleges of Belfast, Cork, and Galway have been built and endowed. A sum of 100,000*l.* was assigned out of the Consolidated Fund for purchasing the sites, and erecting and furnishing the buildings of the three Colleges. Her Majesty and her successors were made visitors, with power to appoint, by sign manual, persons to execute the office. The appointment of the presidents, vice-presidents, and professors, was entrusted to the Crown, until parliament should otherwise determine. The Commissioners of the Treasury were empowered to issue annually a sum not exceeding 7000*l.* for the payment of salaries and other expenses in each college; it being moreover provided that reasonable fees should be exigible from the students. Lecture-rooms were directed to be assigned for religious instruction: and it was enacted that no student should be allowed to attend any of the colleges unless he should reside with his parent or guardian, or some near relation, or with a tutor or master of a boarding-house licensed by the president, or in a hall founded and endowed for the reception of students.

A president and vice-president for each college were soon after nominated, and the erection of the buildings was begun. The other appointments were made in August 1849, and the three colleges were opened in the end of October following. An additional sum of 12,000*l.* had shortly before been granted by Parliament for providing them with libraries, philosophical instruments, and some other requisites.

The peculiarity of and the need for such colleges arose from the state of religious feeling in Ireland. The greatest proportion of the people are Roman Catholics, and there is a large number of Presbyterians; but in Trinity College, Dublin, there are no arrangements which even recognise the existence of any form of religious belief but that of the Established Church; not only is the student who may hold any other creed (in so far as such dissenting students are admitted at all) left without any spiritual superintendence whatever, but the entire system of teaching and discipline is in the hands of members of the Church established by law, and is regulated and administered in all respects in conformity with the doctrines and ritual of that Church. Notwithstanding considerable opposition the experiment has succeeded. The colleges are attended by students of all religious creeds; but while thus free to all, the morals and the peculiar faith of the student are sedulously attended to.

Neither in England have the efforts to promote education been confined to the poor. At Durham the bishop and dean and chapter obtained an act of Parliament in 1832, authorising the institution and endowment of a university, which was opened for students in October 1833. In 1837 a royal charter of incorporation was obtained by which the style and title of "the Warden, Masters, and Scholars of the University of Durham" was given to the institution. The charter gave the power of conferring degrees, and confirmed the rights and privileges assured to it by act of Parliament, usually enjoyed by chartered universities. The bishop is appointed visitor; the dean of Durham is constituted warden. To the professorships of divinity and ecclesiastical history and of Greek and classical literature, which are both in the patronage of the bishop, canonries in the cathedral are annexed. The professor of mathematics and astronomy, the readers in law, Hebrew, history and polite literature, and natural philosophy, the lecturer on chemistry and mineralogy, and other officers of the university, are appointed by the dean and chapter. Of University College the warden of the university is master. Bishop Hatfield's Hall, instituted in 1846, is for divinity students. It has four tutors, one of whom is principal, a censor, and a chaplain. The academical year consists of three terms of not less than eight weeks each, which are called Michaelmas, Epiphany, and Easter Terms. The age of admission to the academical course is from 16 to 21; and for the divinity course, between 21 and 26; beyond this age students must be admitted by special leave. Care has been taken that the necessary expenses of students shall be as moderate as is consistent with comfort, and any approach to extravagance is sedulously guarded against.

In 1854 an act of Parliament extended the right enjoyed by the graduates of Oxford and Cambridge to practise physic without farther examination, to the graduates in medicine of the University of London. In the same year by another act, a commission was appointed to draw up regulations for the improvement of Oxford University, and in 1857 a similar one was passed for Cambridge. Under these commissions many valuable improvements have been effected, and more may be confidently expected. Among those effected are the breaking up of the close scholarships (especially those of Winchester school), and throwing them open to general competition; the dispensation from the taking of a number of unnecessary oaths; the establishment of private halls; and the abolishing of the oath on matriculation and on taking the degree of B.A.; by which last regulation Dissenters are admitted to the whole advantages of a university education. In Scotland also an agitation is being made for some improvement in the universities.

SCHOONER. [Ship.]

SCHWEINFURTH GREEN. [Copper.]

SCIATICA is a name often applied to all rheumatic affections about the hip-joint and the back of the thigh, but which is more properly adapted to a disease of the sciatic nerve, either inflammatory, or similar in its nature to those which in other parts are designated Neuralgia, or Tic doloureux. The pain in sciatica commonly follows, or is situated in some part of, the course of the sciatic nerve, extending from the inner portion of the buttock along the back of the thigh to the ham, and is sometimes continued to the foot along the track of the nerves of the leg. It occurs specially in adults and in old persons, and more particularly in those that have been subject to rheumatism; the pain is generally remittent, and seldom ceases altogether; but is commonly aggravated in the evening. For the treatment and other circumstances connected with sciatica, we must refer to the articles Neuralgia and Rheumatism.

SCIENCE. The word *scientia*, in real Latin, simply means knowledge, and we must attribute the subsequent application of the word to particular kinds of knowledge, to causes similar to those which have influenced the use of the equally general term Mathematics. It does not appear that in the earlier parts of the middle ages *science* had any distinct meaning as opposed either to *literature* or to *art*. Almost at the earliest establishment of universities, the great preliminary branches of knowledge were separated from the rest under the name of *liberal arts*; that is to say, the Trivium, containing grammar, logic, and rhetoric; and the Quadrivium, containing arithmetic, geometry, astronomy, and music. If theology, law, and medicine were called sciences, it was not in any distinctive sense, and we are inclined to think that *scientia* must then have been rather a term subaltern to art, than opposed to it. We find Roger Bacon ('Op. Maj.,' cap. xv.) speaking of the nine mathematical sciences, and the six great natural sciences, which contain under them many other sciences: and his contemporary Robert of Lincoln ('Tract. de Art. Lib.'), after laying it down that the arts (not sciences), of which it is the office "operationes humanas corrigendo ad perfectionem ducere," are seven in number, proceeds to describe them without a single use of the word science. How the word grew it is not our business to inquire closely; but by the middle of the 16th century the word *science* had begun to appear as denoting connected and demonstrated knowledge, in opposition to *art*, which signified digested rules of operation not connected with each other by deduction from common first principles. Thus Tartaglia, a writer on algebra (which was then, and most properly, called only an *art; ars magna*, or arte maggiore), styles Euclid, in the preface to his edition of the Elements, "the sole guide to the mathematical *sciences*." By the middle of the 17th century, the term science was freely used in the sense which it has never since lost, namely, that in which it is opposed to literature. But the old distinction of science as opposed to art has still remained, though the two terms, in this sense, have been in great measure superseded by theory and practice; but improperly, for the distinction between science and art is one thing, and that between theory and practice another. [THEORY.]

A science, as distinguished from an art, is a body of truths, the common first principles of which are supposed to be known and separated, so that the individual truths, even though some or all may be clear in themselves, have a guarantee that they could have been discovered and known, either with certainty or with such probability as the subject admits of, by other means than their own evidence. It is not necessary that these truths should have been discovered by a scientific process; it is enough that they admit of such treatment subsequently. The telescope, for instance, may have been discovered accidentally; but it can now be demonstrated beforehand that such an instrument must produce the effect which it is known to produce, and the rules for its construction may be deduced from the simple fundamental properties of light. In the sense of the word above used, the number of perfect sciences is not so great as is commonly supposed; for many branches of knowledge which bear the name are not perfect sciences, such as medicine, zoology, and geology; in all of these, large classifications have been made, many principles have been deduced which seem to be of universal application, and much has been done to make these known principles point out the direction of inquiry; but it would be idle to say that either of them is a science in the sense in which astronomy is a science.

Science, as opposed to literature, means any branch of knowledge in which the affections of mind or matter are to be made the subject of reasoning, with a view to discover and apply first principles. The distinctions of mental and physical sciences, the subdivision of the former into ethical and psychological, &c., whatever terms may be employed, are real and useful. But as it is not the object here to classify human knowledge, but only to give a slight account of the mode of using a word, we may pass on to its common signification.

By science, in popular language, is meant simply mathematical, physical, or natural science, not with reference to principles, but to results. Calculation, collection of natural objects, construction of models, use of philosophical instruments, any or either, is science, or part of science; and a man of science (man of *a* science, or man of the art which is built upon *a* science, would frequently be a correct description) may be either a mathematician, mechanist, engineer, medical practitioner, astronomer, geologist, electrician, zoologist, ornithologist, &c. To this sort of designation there can be no objection in itself, and it is convenient as distinguishing followers of science, or of a science, from those of literature. But it is not sufficiently precise in itself to distinguish the followers of different sciences from one another. When a literary man is named, his pursuit is generally indicated; the historian, the antiquary, the poet, the novelist, the politician, the scholar, and the linguist, are not confounded by means of a general term: insomuch that "literary man," by itself, generally implies one of information, but not of distinguished depth in any one particular branch. But the inquirer into the sciences of electricity and magnetism, for example, has no name to distinguish him from the observer and classifier of insects; that is to say, the proper technical names are not familiar to the world at large. But this is the least inconvenience. When the word science comes to be used in its high and proper sense, indicative of truth discovered, error prevented, inquiry organised, judicious habits formed, and mental energy strengthened, it must be difficult for those who are used to the common sense of the word to imagine the truth of many things which are said about it. "All we require is, that he will hold his former opinions and judgments without bigotry, retain till he shall see reason to question them, be ready to resign them when fairly proved untenable, and to doubt them when the weight of probability is shown to lie against them. If he refuse this, he is *incapable of science*." Now this, though the word of a good authority, and perfectly true, is nevertheless notoriously false in the common sense of the word science: a man may be incapable of the preceding state of mind, and may be a *man of science*. There is no remedy for this confusion of terms, except that which every one must make for himself, by attention to the different senses of the word, the higher and the lower.

SCIENCE AND ART, DEPARTMENT OF. This department of the Committee of Privy Council on Education owes its origin to the suggestions contained in the Second Report of the Commissioners for the Exhibition of 1851. After urging the necessity of the industrial classes of this country receiving more systematic instruction in science and art in order to enable them to maintain their pre-eminence in the neutral markets of the world, the Commissioners impressed on the government the advantages which would result from bringing the various institutions connected with Science and Art that were supported by the public funds, into close connection with each other, instead of their remaining under different departments of the government. The government took a favourable view of the suggestion; and, as a part of the "comprehensive scheme for the advancement of the fine arts and of practical science," announced from the throne at the opening of the session of 1852-53, the Lords of the Treasury, in March, 1853, gave their formal concurrence to the proposed arrangement of the Privy Council to "unite in one department, under the Board of Trade, with the Departments of Practical Art and Science, the kindred and analogous institutions of the Government School of Mines and Science, the Museum of Practical Geology, the Geological Survey, the Museum Irish Industry, and the Royal Dublin Society, all of which are in part supported by parliamentary grants;" and, the Treasury minute proceeds, "my Lords have given directions that the estimates for all these institutions shall be brought together under the general head of 'Board of Trade Department of Science and Art.'" The immediate purpose of this amalgamation, it was declared, was to bring the whole of these institutions under one common superintendence, to establish a Central Metropolitan School of Practical Science as well as of Art, and to encourage and extend the formation of minor local institutions which should be in connection with, and assisted by, the central institutions, but as far as possible self-supporting and under the management of the local authorities.

As was said above, the institutions thus brought together under one department, were all in part supported by parliamentary grants. The sums voted for each in the year previous to the amalgamation were: Government School of Mines and Science, 800*l.*; Museum of Practical Geology, 5272*l.*; Geological Survey, 5500*l.*; Museum of Irish Industry, 3348*l.*; Royal Dublin Society, 6340*l.*; Department of Practical Art, including the provincial Schools of Design, 17,920*l.*; in all, 39,181*l.*: but the sum actually granted was 41,586*l.*; additions having been sanctioned of 150*l.* to the School of Mines, and 2255*l.* to the Department of Practical Art.

Of these institutions the character may be briefly indicated. The Government School of Mines and of Science applied to the Arts was founded in 1851, in consequence of memorials addressed to government by the mining districts of the United Kingdom, in which it was shown that the schools for the instruction of persons engaged in mining pursuits by various Continental governments had much increased the economy, efficiency, and safety of mining operations in the countries in which they had been established, and that the want of similar schools had long been felt in the mining districts of this kingdom. The Government School of Mines was accordingly opened in connection with the Museum of Practical Geology in 1851. It is now merged in the Metropolitan School of Science applied to Mining and the Arts, which forms one of the two great branches of the department which is the subject of this article. The Museum of Practical Geology, which will be noticed more fully presently, was in 1850 removed to the building erected for its reception in Jermyn Street, St. James's. Ever since the establishment of the Museum, the Geological Survey of the United Kingdom has been carried on in connection with it. To these institutions we may add the Royal College of Chemistry, founded in 1845, it having been, in 1853, transferred to the Department of Science and Art.

The Department of Practical Art was a development, or rather reconstitution, of the central Schools of Design, originally founded in 1837, in accordance with the recommendations of a committee of the House of Commons. The Department of Practical Art was created but a short time before its amalgamation with the other institutions in the Department of Science and Art, and before it had come into full operation as a separate institution.

The Royal Dublin Society for the improvement of husbandry, manufactures, and other useful arts and sciences, was founded in 1731, and incorporated by royal charter in 1749. It possesses a valuable museum of natural history; an agricultural museum; an excellent library; a museum of sculpture, casts, &c. From its establishment, we believe, it has had its schools of painting, sculpture, and the fine arts, from which many of the best native artists have proceeded. It has also a good chemical laboratory; and a convenient theatre for the delivery of lectures. The Botanic Gardens at Glasnevin belong to the Society, and the Zoological Gardens, Phœnix Park, are in connection with it. Though amalgamated with the Department of Science and Art, the Society is conducted wholly by its own council, the duties of the department being confined to supervision and suggestion.

The Museum of Irish Industry was established by the government in 1845, and placed under the direction of Sir Robert Kane, so honourably distinguished for investigations in connection with the industrial pursuits of Ireland. In object, the Museum of Irish Industry resembles pretty closely the London Museum of Practical Geology, but takes a somewhat wider and more diversified range. It has a staff of professors who lecture in the theatre of the Royal Dublin Society; the professors, since the union with the Department of Science and Art, being common to the two institutions. The system of lectures, which has some peculiarities, is an extension of that previously adopted by the Royal Dublin Society. Short courses are given during the day, chiefly to the upper classes; and other courses are given in the evenings, chiefly to the sons and assistants of persons engaged in trade, and to artisans. Examinations take place at the end of every course, when prizes are awarded to the more successful students, and a general competitive examination is held at the end of every year. In addition to this, lecturers on science are sent to the provincial towns, and local examinations take place at stated periods in connection with their instruction.

The institutions which were united to form the Department of Science and Art, it will have been noticed, all belonged to England and Ireland. But in 1854 the necessary steps were taken for the formation of an Industrial Museum for Scotland, similar to those of London and Dublin. A site was purchased by the government near the University of Edinburgh for the building; and the museum belonging to the town-council, and the valuable collection of models, minerals, &c., of the Highland Society were transferred to the Crown, and thus an excellent basis was obtained for the proposed museum. The museum was placed under the direction of Dr. George Wilson, through whose zealous exertions singularly rapid progress was made in forming the collections, which at his death, in November, 1859, already numbered upwards of 10,300 specimens. A Museum of Natural History, Edinburgh, has also been formed in connection with the Department of Science and Art. A building is now in course of erection which is intended to contain both these museums.

Originally the Department of Science and Art was constituted a section of the Board of Trade, but in February, 1856, it was, by an order in council, transferred to the Committee of Privy Council on Education. Of that committee it now forms a distinct division: its functions having reference to the secondary instruction of all classes of the community in those principles of art and science which conduce to the industrial interests of the country, while the functions of the other division of the Committee of Education refer to the primary instruction of the young; the two divisions being kept entirely unconnected. The Department itself consists of two sections—a School of Science, with its connected museums and affiliated institutions, having its head-quarters at Jermyn Street; and a School of Art, with its various collections and associated schools, having its head-quarters at South Kensington, where also are the offices of the Department. The sum voted for the Department of Science and Art in 1860 was 94,951*l.*, being an increase of 11,709*l.* over the previous year, and more than double the sum voted for the several institutions prior to their consolidation.

It remains to notice shortly the present position of the two sections of the Department. The Metropolitan School of Science, applied to mining and the arts, has, in the words of the official prospectus, "for its chief object and distinctive character (to which everything else is subsidiary), to give a practical direction to the course of scientific study." And the course of instruction which is imparted to the student, while it does not profess to qualify him to undertake the direction of mining or other technical operations, is intended in combination with future training, to "render him in the highest degree competent, not only to engage in any special branch of industry, but to promote its further development." The institution is under the general supervision of a director, Sir R. I. Murchison, the eminent geologist, who succeeded the late Sir H. T. de la Beche, and the instruction is given by professors of chemistry, natural history, applied to geology, physical science, applied to mechanics and mechanical drawing, metallurgy, geology, and mining and mineralogy, each men of the highest standing in their respective departments. The mode of instruction is by lectures, by written and oral examinations, by practical teaching in the laboratories and drawing office, and by field surveying and geological and natural history excursions. The field of study is separated into—a general division, for those who desire a general knowledge of science; a mining and metallurgical division; a technical division, for those who propose to engage in arts or manufactures depending chiefly either on chemical or on mechanical principles. For each of these divisions the course of study extends over two years, of three terms in each. Students must be at least 16 years of age on admission. Several exhibitions have been founded, to be competed for by matriculated students. The lectures are open to occasional or non-matriculated students, on payment of a somewhat higher fee; and special short courses of evening lectures, at an extremely low fee, are given every session to working men only, and are attended always by as large a number (600) of diligent students of that class as the theatre will accommodate.

The Metropolitan School of Science enjoys rare advantages from the ready access which the students have to the treasures accumulated in the museum at Jermyn Street. These consist of the extensive and admirably arranged collections formed during the progress of the geological survey of the United Kingdom, "illustrative of the structure of the British islands, and of the applications of geology to the useful purposes of life," under the able directors and indefatigable staff of the survey. To these have been added a numerous selection of models of mines, mining tools, and working models of mining machinery; of tools, and models, and specimens of machinery for general purposes; of historical specimens of manufactures in glass, earthenware, and the metals; and of foreign and colonial mineral productions. Many of the specimens are of great rarity and beauty, but their main interest lies in their technical or scientific value, and the whole are carefully classified and conveniently arranged. The museum is open gratuitously to the public during five days of the week. In 1859 it was visited by 25,309 persons.

The maps and sections of the geological survey, and a large collection of plans and sections of mines, &c., belonging to the Mining Record Office, are deposited in the building in Jermyn Street. The chemical laboratories are those of the Royal College of Chemistry in Oxford Street, which, as already mentioned, became in 1854 the property of the Government.

In connection with the Metropolitan School of Science, special schools of science, or classes for instruction in science, have been established since 1853 in several of the large manufacturing, mining, and pottery towns. These schools, in accordance with the principle laid down by the government on the formation of the Department of Science and Art, are in a great measure self-supporting, the Department exercising a certain amount of control, and, in return, affording a limited pecuniary aid to certified masters of the schools. Certificates are also granted by the Science Inspectors to any teachers who pass a satisfactory examination in—1, practical and descriptive geometry, with mechanical and machine drawing; 2, physics, mechanical and experimental; 3, chemistry; 4, geology; 5, natural history: and those who are successful "receive certificate allowances of 20*l.*, 15*l.*, or 10*l.*, in each, while engaged in teaching."

Navigation Schools have also been established in connection with the Department. They are intended to afford instruction to officers of the mercantile marine on the subjects of their examination for certificates of the Board of Trade, and similar instruction to youth about to enter on a seafaring life. Besides three in London, Navigation Schools have been opened in nine of the principal outports, and they seem on the whole to have met with a fair amount of success. In 1859 there were 2490 students in the Navigation Schools.

The Art Schools are of older date than the Schools of Science, and, appealing to a wider circle, have almost necessarily made greater numerical progress. The Art branch of the Department has, as we have already said, its head-quarters at South Kensington, on the estate purchased by the Commissioners of the Exhibition of 1851, and is a development or reorganisation of the old Schools of Design. As at present organised, the special objects of the Art section of the Department are in the words of the official programme—"1. To train male and female teachers to give instruction in Art, to certify them when qualified, and to make them annual fixed payments, varying according to their acquirements. 2. To aid and assist committees in the provinces desirous of establishing Schools of Art. 3. To hold public inspections and examinations, and to award medals and prizes to the most deserving candidates. 4. To collect together works of art, pictures, &c., in the central Museum, and books and engravings in the central Library. 5. To circulate among the Schools of Art objects from the Museum, and books and engravings from the Library."

The buildings at South Kensington include the offices of the Department, the Training School for Masters and Mistresses, the Normal Central School of Art, the Art Library, and the Museum.

"The Training School has for its special object the education of Art-teachers, male and female, but it also aids in supplying certificated Art-masters or mistresses to teach drawing to schools in connection with the Committee of Council on Education. The course of studies embraces, besides all the ordinary branches of Art-Education, instruction in various direct applications of Art-power to mechanical and manufacturing industry. It comprehends the following subjects:—Free-hand, architectural, and mechanical drawing; practical geometry and perspective; painting in oil, tempera, and water-colours; and modelling, moulding, and casting. These classes include architectural and other ornaments, flowers, landscape, objects of still-life, &c., the figure from the antique and the life, and the study of anatomy as applicable to Art; and some technical studies, such as enamel painting, and drawing and engraving on wood. The students have full access to the Museum and Library, either for consultation or copying, as well as to all the public lectures of the Department. Special classes are arranged in order to qualify schoolmasters and schoolmistresses of parochial and other schools to teach elementary drawing as a part of general education."

In connection with the Central School of Art there are nine Metropolitan District Schools, and one school for female students only. The provincial Schools of Art have increased greatly in number since the formation of the Department. These schools are, like the Schools of Science, in the main self-supporting, but the Department assists in paying the certified teachers, and in various ways aids in providing the school materials, and in rendering assistance to the institution. They are now in all eighty-six in number; and at the last return they were the means of affording instruction in drawing and painting to above 84,000 students—but this number includes, besides students in the art schools, pupils in training colleges, and children in various classes of primary schools "under instruction in drawing," who can hardly in fairness be ranked as Art-students. The Department, in fact, now, besides the training which it affords in its central and metropolitan schools, and the special Provincial Schools of Art in connection with it, proffers the services of a certified teacher in drawing to any school or schools, furnishing an aggregate of 500 children for instruction in drawing; and it further offers the aid to such schools of examinations and prizes, at stated periods.

The Museum of the Department at South Kensington will be noticed under SOUTH KENSINGTON MUSEUM.

SCILLA, or as Steinheil, who separates it and another species (S. Pancratio) from the old genus, terms it, Squilla Maritima, also Urginea Scilla (Steinh.), or Sea-onion, is a plant common on the sandy shores of the Mediterranean, Portugal, the Levant, and in North Russia. It is imported into Britain from Malta and other parts of the Mediterranean, and also from Petersburg and Copenhagen. The officinal part is the bulb, of which there are two varieties: the one large and whitish externally; the other smaller, of a brownish-red colour. The former is preferred in England, the latter in Germany. This appears to be the Squilla Pancration of Steinheil. The bulb part partakes in its outer part of the nature of a *tunicated*, in its inner, of the nature of a *scaly* bulb. It abounds in an acrid, mucilaginous juice, with an alliaceous odour, and a bitter, acrid, nauseous taste. It is imported whole, or cut in slices and dried. The bulb is not of equal potency in every part. The outer, dry, scarious integuments are devoid of activity; the subsequent fleshy scales are the most powerful; while the internal young ones are mucilaginous, nearly insipid, and powerless. It is clear from this that the best mode of drying squill is to decorticate it by removing the outer segments, and carefully separating the intermediate large fleshy scales, to dry these quickly, and to leave the central ones as inefficient. The drying should be conducted quickly, but not by too high a temperature, lest some of the active principles be driven off. Putting the thick scales on sieves or willow-baskets in a moderately heated oven, or in a room fitted with a drying apparatus, is the best plan. Stringing them on threads and drying them slowly, by which they become paper-like and tasteless, is bad. The common method however is to cut the bulb into transverse slices, which, when dried, have a horny appearance, and are semi-translucent. In this case the active and inactive portions are blended together. After whatever means are used to dry them, it is necessary that the squills be kept in well-stoppered bottles in a dry place, as, in common with all bulbous plants, they quickly absorb moisture from the atmosphere. In the process of drying, four-fifths of the weight are lost.

The chief constituents of squill are—an acrid bitter principle (*Scillitin*), sugar, mucilage, salts of citrate or tartrate of lime, also phosphate of lime, tannin, and a volatile acrid principle, which in the process of decorticating fresh squill causes a flow of tears from the eyes, sneezing, &c., and severe itching, with burning pains of the hands and arms, yet without obvious swelling or inflammation. A scale of fresh squill applied to the skin rapidly excites rubefaction and vesication, like a sinapism. Squill in large dose is unquestionably poisonous, but in many cases it fortunately acts as its own antidote, by causing vomiting. But even in moderate doses it may still do much harm, by its stimulating effect, if prematurely employed, as it often is, as a popular or domestic medicine in the early stages of colds and coughs. It is for the second stage alone of these that it is suited. It augments the secretion from most mucous surfaces, and also stimulates the kidneys, and sometimes the skin. For the reason above stated, it is unsuited to inflammatory dropsies, but it is proper for the effusions occurring in leucophlegmatic subjects, depending on debility, and for general anasarca rather than local effusions. Its diuretic properties are increased by the previous moderate use of mild mercurials, and by uniting it with other diuretics, either vegetable or saline, and still more by adding bisulphate of quinia or other tonics. Its expectorant properties are greatly heightened by the addition of tonics, such as exist in the Mistura Cascarillæ Composita. Squill is a very improper emetic for young children, as it seriously irritates the coat of the stomach.

SCILLITIN, the bitter principle of squills (*Scilla maritima*). This is obtained by first inspissating the juice of the root, then treating it with alcohol, and after having evaporated the solution, dissolving the residue in water; to the solution acetate of lead is to be added, which gives a precipitate that is to be separated; afterwards sulphuretted hydrogen is to be passed into the solution, and it is finally to be evaporated. By this process scillitin is obtained, which has the following properties: it is colourless, friable, of a bitter taste at first, and afterwards nauseous and sweetish, and attracts moisture from the air. It is soluble in alcohol and in ether; its solution is not precipitated by acetate of lead. It is emetic and purgative, and may even occasion death.

SCIOPTIC BALL is a globe of wood about 5 inches diameter, with a cylindrical perforation 2½ inches diameter passing centrally through it, and having at one extremity of the perforation a glass lens. The globe or ball is, by means of screws, fixed in a socket, which is made in a board about 8 or 10 inches square, in such a manner that while it cannot fall out, it is capable of being turned on its centre, to a small extent, in any direction.

The board being screwed to a window-shutter, or to the vertical face of a building in which an aperture has been made for the reception of the globe, the rays of light from external objects, after being refracted in the lens, form pleasing images of those objects on the opposite wall of the apartment, or on a white screen placed in a vertical position to receive the light; the apartment being darkened in order that the images may be distinct. The images on a vertical screen being inverted, two arms generally project from the board, within the room, and carry a plane mirror which turns on an axis so as to allow the rays of light, after passing through the lens, to fall on a screen placed in a horizontal position: by this means the spectators are enabled to see the images in erect positions. [CAMERA LUCIDA AND CAMERA OBSCURA.]

When the construction of the building is such as to allow the ball and lens to be fixed at an aperture in the roof, a plane mirror being placed above it at an angle of 45 degrees with the horizon, so as to reflect the rays from external objects down on the lens, the images formed on a screen within the darkened apartment are more distinctly formed and more conveniently seen. An apparatus of this nature was formerly applied to the roof of a building connected with the astronomical observatories at Greenwich, Edinburgh, and Glasgow, for the amusement of visitors.

SCIRE FACIAS, is a writ used to enforce the execution of, or vacate, some already existing record. It directs the sheriff to give notice ("Scire facias," whence the name) to the party against whom it is obtained to appear and show cause why the purpose of it shall not be effected. A summons to this effect should be served on the party, whose duty then is to enter an appearance, after which a declaration is delivered to him, to which he may plead, or demur, the subsequent proceedings being analogous to those in an ordinary action. *Scire facias* may be resorted to,—

1. Where, the parties remaining the same, it is necessary to revive or set in operation the record.
2. Where another party seeks to take the benefit of it, or becomes chargeable, or is injured, by it.

Formerly, when a year and a day had elapsed since judgment was signed, the law presumed that the judgment had been satisfied; and execution could not issue against the defendant until he had an opportunity, by means of the notice given him under a *scire facias*, of appearing and showing any cause which might exist why execution should not issue against him. But a simpler, less expensive, and less dilatory method of proceeding was provided by the Common Law Procedure Acts, 1852 and 1853, the former statute having at the same time extended the period during which execution may issue, from a year and a day to *six years*. In case of a change by death, marriage, bankruptcy, or otherwise, in one of the parties to an action, the representative of that party may now enter a suggestion of the fact, and put himself in his place. The opposite party is also enabled to call upon the representative to do so, and if he fails to stop the proceedings. The proceeding by suggestion on the roll is adapted to the most simple cases of change in the parties to a suit. If it be not adopted, a writ of *Revivor*, as it is now called, may be issued, the object of which is the same as that of a *scire facias*. It is, however, directed to the party and not to the sheriff, as was the writ of *sci. fa.*, and it may be served anywhere by the party, and not as formerly by the sheriff of the county where the *venue* in the original action was laid. The subsequent proceedings in *Revivor* resemble those of an ordinary action.

The writ of *scire facias* is not itself abolished. In some cases it is still the only method of proceeding; for instance, to enforce a judgment against the *terre tenants* of a deceased judgment debtor. So when a plaintiff, having had execution by elegit, under which he obtains possession of a moiety of the rents and profits of the defendant's land, has had the debt satisfied by payment or from the profits of the land, *scire facias* may be brought to recover the land.

A *scire facias*, again, is the only proceeding for the purpose of repealing letters patent by which the crown has made a grant injurious to some party, as where he has granted the same thing which he had already granted to another person; or a new market or fair is granted to the prejudice of an ancient one, &c. The sovereign may also have a *scire facias* to repeal his own grant, and any subject who is injured by it may petition the crown to use the royal name for its repeal. A man may have a *scire facias* to recover the money from a sheriff who has levied under a *fieri facias* and retains the proceeds.

SCIRRHUS. [CANCER.]

SCLEROTICUM. [ERGOT.]

SCO'LIA (from σκολιός, crooked) were short drinking-songs, which were invented and cultivated by the ancient Greeks. The origin of the name "crooked songs" has been explained by the ancients themselves in a variety of ways, of which we shall mention only two. Some supposed that these songs were called scolia because they were not sung by the guests in succession, and in the order in which they lay on their couches, but irregularly, and without any definite order; others thought that the name referred to peculiarities in their metrical forms, or, which is the most probable of all, to certain liberties which the singer might take in delivering his song. The first of these two opinions, though not a probable account of the origin of the name scolion, yet contains the true account of the manner in which scolia were sung. Artemon ('Ap. Athen.,' xv.) and Plutarch ('Sympos.') distinguish three kinds of Scolia, namely, those which were sung in a chorus by a whole company, those which were sung by all the guests in succession, and those which were only sung by well skilled persons, who, when they ceased, called upon another member of the company to go on. But the name scolion seems, in the first two of these cases, to be applied improperly, as they must rather be considered as a kind of prelude to the real scolia, which is in fact implied in the description given by Plutarch. These drinking songs were generally accompanied by the lyre, which was handed by the last singer to his successor: in some cases, however, when persons were unable to play the lyre, a laurel or myrtle branch was handed to them. Scolia were first sung and composed by the Greeks of the Æolian race, and especially in Lesbos; but the custom was thence transferred into Attica, where it subsequently became a universal practice to sing scolia at repasts. The contents of these short songs—which, in the specimens still extant, seldom exceed four lines—varied according to time and circumstances. The metres in which scolia were written are of a lively and animated character, and, on the whole, resemble those used by the lyric poets of the Æolian school. Terpander is said to have been the first who wrote scolia, and he was followed by Alcæus, Sappho, Anacreon, Praxilla, Simonides, Pindar, and many others. A collection of Greek scolia still extant has been made by C. D. Ilgen, in his 'Σκολιά: id est Carmina convivialia Græcorum, metris suis restituta et animadversionibus illustrata,' Jena, 1798. The number of scolia in this collection is fifty, but they are not all real scolia.

(Compare Müller, *Hist. of Greek Lit.*, &c.; Bode, *Geschichte der Hellenischen Dichtkunst*, vol. ii., part. 2.)

SCOPARIN. ($C_{42}H_{22}O_{20}$?). This substance appears to be the diuretic principle of the *Spartium scoparium*. The concentrated infusion of this plant solidifies on cooling to a brownish-green jelly, which consists of scoparin, chlorophylle, and *spartein*. The chlorophylle is separated by water which dissolves the other two substances. During the spontaneous evaporation of this aqueous solution the scoparin separates in the form of small yellow crystals, which are slightly soluble in cold water, but very soluble in boiling water or boiling alcohol. Scoparin is inodorous and insipid, and without action upon test papers. Nitric acid transforms it into picric acid.

SCOPA'RIUS, CY'TISUS SCOPA'RIUS, or BROOM, a shrub extremely common on uncultivated ground, heaths, &c., of most parts of Britain. The young tops or twigs when bruised, have an unpleasant odour, and a disagreeable nauseous taste. The seeds are emetic, and probably contain cytisine, an alkaloid found in the seeds of the Cytisus Laburnum, which possesses emetic, and, in large doses, poisonous properties. But Dr. Stenhouse thinks the broom has a volatile narcotic principle, to which he gives the name of Spartiine. It also has an inert principle which he calls Scoparine. An infusion made with cold water is equally efficacious as the decoction, and much more palatable.

Broom tops boiled in water form a decoction which acts both on the bowels and kidneys. It is unquestionably a valuable diuretic, and many obstinate cases of dropsies have yielded to the use of this indigenous remedy which had resisted other means. Its diuretic properties may be increased by the addition of juniper berries and dandelion, to form the decoction, as now directed in the Pharmacopœia, and by adding to each dose, acetate, tartrate, or bitartrate of potash.

SCORDEIN. An aromatic non-azotised yellow substance found in the *Teucrium Scordium*.

SCORE, in music, is a collection of all the vocal and instrumental parts of a composition, arranged on staves, one above the other, and bar for bar, presenting at once, to the eye of a skilful musician, the effect of the whole band as the composition proceeds.

SCORPIUS, or SCORPIO (the Scorpion), a constellation of the zodiac, lying between Libra and Sagittarius, and bounded north and south by Ophiuchus and Lupus. It contains one star of the first magnitude, which with Spica Virginis, and Arcturus, forms a conspicuous triangle. As noticed in LIBRA, this constellation was formerly two signs of the Greek zodiac, the claws occupying the place of Libra. The story is that the chelæ or claws of the Scorpion were drawn back by Roman astronomers, and the constellation Libra added in honour of Julius Cæsar, at whose death a new star was said to have appeared in that part of the heavens. This story is alluded to, not very distinctly, by Virgil; Hyginus is totally silent about it, merely saying that his countrymen call one part of this constellation Libra. Manilius uses both Libra and Chelæ. Ptolemy does not mention Libra in his catalogue, though he does elsewhere. Dupuis contends, from its presence in the most ancient Indian and Persian zodiacs, that it is in reality as ancient as the rest: and indeed it is not unlikely that the Greeks may have derived their zodiac from some nation in which the term for scales was confounded with that for claws, either by a synonyme in the language itself, or by mistranslation on their part.

The following are the principal stars :—

Character.	No. in Catalogue of Flamsteed. (Piazzi.)	No. in Catalogue of British Association.	Magnitude.
ρ	5	5272	4
π	6	5289	3
δ	7	5308	3
β	8	5329	2
ν	14	5382	4
α	21	5498	1
ε	26	5632	3
υ	34	5901	4
λ	35	5915	3
κ	(174)	5970	3
μ¹	(189)	5638	3
μ²	(193)	5640	4
η	(302)	5778	4

SCOT, from *sceat*, an Anglo-Saxon word originally signifying "a part" or "portion." It appears also, at least in composition, to have meant any sum paid; thus, sawl-sceat, soul-scot, or soul-shot, was the name for the ecclesiastical due payable at the open grave for the benefit of the soul of the deceased. Previous to the Reform Act, 2 Wm. IV., c. 45, in many boroughs the payment of scot and lot constituted a qualification as a voter for a member of parliament of the borough. Those who possessed such qualification at the time of passing the Act had, under certain conditions, their rights reserved to them.

The qualification consists in the payment of the rates which are allotted to each person as the proportion to be contributed by him. The criterion adopted for the purpose of ascertaining the scot and lot voters of a borough, is the poor-rate of the respective parishes comprised in it.

(Rogers *On Elections.*)

SCOTLAND, CHURCH OF. The constitution of this church is considered under the heads of GENERAL ASSEMBLY; PRESBYTERIANS; and SESSION, KIRK. An important portion of its recent history is narrated under the head FREE CHURCH. It remains only chronologically to mention the chief events in the history of the church. The main struggles of the Reformation in Scotland date at the middle of the 16th century. On August 1st, 1560, a convention parliament abolished the Romish hierarchy, and on 20th December of the same year, the first general assembly was held in Edinburgh. The tercentenary of this event was celebrated throughout Scotland and by Presbyterians in England on December 20, 1860. In 1561 the 'First Book of Discipline,' still an important part of the ecclesiastical code of the established church and the various sects into which the Presbyterians of Scotland are now divided, was compiled. The fundamental principles of the reformed church were passed into an act of parliament in 1567 (Act 1567, c. 3), with the title, 'The Confession of the Faith and Doctrine believed and possessed by the Protestants of Scotland, exhibited to the Estates of the same Parliament, and be their publick Votis authorised, as a Doctrine grounded on the infallible Word of God.' This constitution however had more reference to doctrine than to church polity. It condemned some of the more prominent features of the system of the abjured hierarchy, but did not contain any announcement of the new system of church government. The early constitution of the church as approved of by Knox and his friends, admitted of a difference of grades, certain clergymen being called 'Superintendents' of Provinces, which actually or nearly corresponded with the bounds of the old bishoprics. The Presbyterian polity was at length established by the act of 1592 (c. 114), called 'Ratification of the Libertie of the trew Kirk: of Generall and Synodall Assemblies: of Presbyteries: of Discipline.' In the mean time, those who had been the zealous clerical supporters of the reformation expected that the temporalities of the Roman Catholic church, or at least a considerable portion of them, would be applied to ecclesiastical purposes under the new system. They found however that the powerful laymen who assisted in the demolition of the old system had very different views. They spoke of this notion as "a devout imagination," and kept by far the larger portion of the spoil to themselves. After some hard struggles, in which the national feeling in favour of Presbyterianism was driven very nearly to an outbreak, Episcopacy was re-established by the parliament of 1612. In 1637, the celebrated Liturgy, concocted by Laud and West, on principles more nearly approaching to the Roman Catholic forms than those of the English Liturgy, created the convulsions which ended in the civil war and the re-establishment of Presbytery. On this occasion, great part of the assistance which the Covenanters received from the landed gentry was owing to their dread of a plan for restoring church lands to the hierarchy. On the restoration of Charles II., all the acts of the previous reign subsequent to the year 1623 were 'rescinded' or repealed, and consequently the Episcopal form of church government was restored. The persecutions that arose out of the attempt to enforce this system on a people who abhorred it the more, the more stringently it was enforced on them by penal laws, is well known in history. These laws were relaxed, but not in a manner to satisfy the Presbyterians, by the indulgences of James to all who differed from the established Episcopal church. At the Revolution the Presbyterian form was re-established. The followers of this system, who through the times of the hottest persecution did not ask to be *tolerated* but to be made an exclusive establishment, now thought that the hour was come for the "extermination" of their opponents; but they were told by King William that that was a word not in his vocabulary. In 1699 lay patronage was abolished by an act of the Scottish parliament. It was re-established by an act of the British parliament in 1710. This act created many disputes in the church; it occasioned the secession of 1736, elsewhere mentioned [ERSKINE, EBENEZER, in BIOG. DIV.], and it was the cause of the great severance in 1843 [FREE CHURCH]. In the same year with that severance an act was passed for modifying the right of patronage, called 'Lord Aberdeen's Act' (6 & 7 Vict. c. 61, passed 17th August, 1843): a measure said to have been passed for the purpose of satisfying the scruples of some clergymen who would not remain in the church as it was, but would be content with a less comprehensive measure than the Veto Act. The difference between these two systems was, in the first place, that the Veto Act was passed by authority of the church, its supporters denying that they required the interposition of any lay legislation. By that measure, the simple objection of a certain number of the male communicants without any reason given, was a cause of disqualification to a presentee. By Lord Aberdeen's Act, any members of the congregation may object to the presentee, stating their objections: and the church courts, if they think them good, whether in their general tenor, or with respect to the particular circumstances of the charge, may give effect to them by rejecting the presentee.

SCREEN, in architecture, a partition dividing off some portion of an interior or room from the rest, without similarly contracting or shutting up the space over head; a screen being a partition carried up only to a certain height, so as to admit a view beyond it. Screens are exceedingly beautiful internal features in the Pointed Gothic style, in which they were employed for a variety of purposes, not in churches alone, but in halls and other buildings.

In our larger churches the chancel was separated from the nave by a screen on which was placed the rood. [ROOD LOFT.] From the use to which it was subsequently applied this screen is, in our cathedrals, commonly known as the *organ screen*; it differs from others in being a double screen, so as to form a gallery above, and to admit of stairs leading up to it, in the space between two partitions.

The *altar screen* serves as a back wall to the choir, separating that division of the church from the presbytery or Lady-chapel behind it. [RETABLE.] That erected by Bishop Fox in Winchester cathedral is a splendid stone screen decorated with several tiers of canopied niches; and strikingly similar to it in design is the one by Abbot Whetehamstede at St. Alban's. Though not so designated, the stalls, &c., form lateral screens enclosing the lower part of the choir from the side aisles. Chartres cathedral contains a no less remarkable than fine example of such screen continued round the apsis of the choir, showing itself as a wall carried up to some height above the stalls, and divided into large compartments filled with sculpture. The fronts of chantries, small chapels, &c., in churches, may also be described as screens, most of which are pierced or open-work and tracery. The examples of this class are so numerous, that to particularise any of them would be almost superfluous; we may, however, mention that enclosing the monumental chapel of Prince Arthur, son of Henry VIII., in Worcester cathedral. The tomb of Henry VII., in his chapel at Westminster, is a gorgeous piece of screen-work, executed entirely in metal, and forming an insulated shrine on a very large scale. Westminster Abbey itself contains many fine studies of screens in its chapels and chantries. Of timber screens separating the chancel and altar end from the body of the building, many specimens are to be met with in country churches, and not a few of them are worthy of being studied for the beauty of their design.

Screens of a different character were employed in the halls of domestic and collegiate buildings, for the purpose of cutting off a passage leading to the butteries and offices. Such screens were almost invariably of oak or other wood, and the space over them and the passage behind served as a music gallery. Open-work was rarely if ever introduced into them, but they had generally two open arches, or sometimes square-headed doorways. Several specimens of this class of screens may be seen in Nash's 'Mansions of England in the Olden Times,' some of them, as that in the Hall at Audley-end, profusely adorned with carved panelling and other sculpture; and the one just mentioned is further remarkable for the centre compartment being carried up higher than the rest, though not quite to the ceiling. Other instances occur where the screen is carried up two stories, so as to form either a passage on the chamber floor, or a closed gallery with glazed or latticed apertures. Of this kind are those in the halls at Knowle and at Hatfield.

Screen is also employed to signify a colonnade or wall architecturally decorated, enclosing a court-yard in front of a building, as that for instance of the Admiralty, London. Screens of this kind are sometimes had recourse to in order to connect the advancing parts of a plan together, and prevent a façade being cut up into gaps. It is by this means that the buildings forming the river front of Somerset House have been connected together into a continuous façade by screens assuming the appearance of open Corinthian loggias above spacious bridge like arches. Eminently picturesque in themselves, those features serve to relieve all the rest, and to prevent the monotony that would otherwise take place in so extended a front.

SCREW. This mechanical power generally consists of two parts, one of which is a solid cylinder of wood or metal, on whose convex surface is formed a projecting rib or fillet, frequently called a *thread*, which passes spirally round in such a manner as constantly to make equal angles with lines parallel to the axis of the cylinder. The other is a cylindrical perforation through a block of some material, the surface of the perforation having on it a spiral groove corresponding to the projecting rib or fillet on the solid cylinder. The first of these parts is called a *convex* screw, and the other a *concave* screw, also a *male* and *female* screw.

A just conception of the nature of the line of direction taken by the rib or groove on the surface of the cylinder, may be obtained by drawing on a rectangular paper, whose breadth A B is equal to the circumference of the cylinder, any number of lines A B, C D, E F, &c., equidistant from each other, and perpendicular to the sides of the paper. Then joining the points A and D, C and F, &c., by right lines, and bending the paper on the surface of the cylinder, the lines A D, C F, E H, &c., will, by uniting at their extremities, become the continuous *helix* or spiral curve-line which the thread assumes. When the two parts are in action, the convex screw, being turned round in the other by a power applied at its surface, moves at the same time rectilinearly in the direction of its axis: occasionally however the convex screw is fixed, and then the other being turned about, it acquires at the same time a like rectilinear motion. In either case, the path described by a point on any thread during the time that the screw turns once on its axis, on being developed, becomes equal to A D or C F; and in the same time a point on the axis moves through a space equal to B D or D F.

Fig. 1.

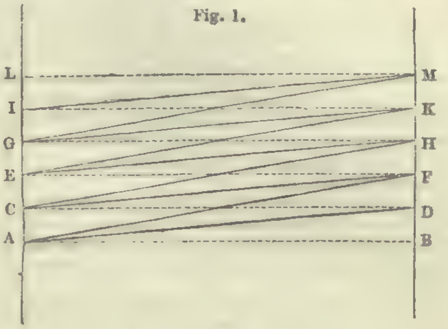
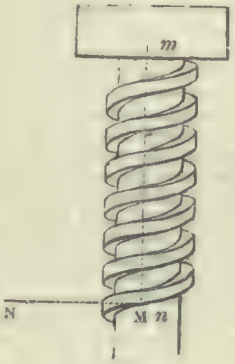


Fig. 2.



As a mechanical power, the screw possesses the properties of an inclined plane; for W representing a weight or pressure at one end of a convex screw, whose threads are thereby made to move in the grooves of the concave screw, let that weight be supposed to act in a direction parallel to the axis, and to be uniformly diffused among all the projecting threads which are at one time in the grooves; also let p be the part of the weight which presses in the direction mM on an elementary portion Mn of the side of a groove in the concave screw. Then Mn may be considered as a small inclined plane, making with mM an angle equal to A D B: and if q be a force which applied at M in the direction N M, touching a circle whose plane passes through the screw perpendicularly to the axis, would prevent the convex screw from turning round; the pressure on Mn and the counteracting force will be in the same circumstances as the weight of any body on an inclined plane and a sustaining power which acts in a direction parallel to the base of a plane, and, by the resolution of forces, the ratio between the pressure and the force will be as the base of the plane is to its height; that is, as A B to B D. Now an equal force q will be in equilibrio with the pressure p on every other elementary portion of the grooves in the concave screw; therefore, there being as many forces $= q$ as there are pressures $= p$, the whole weight W on the screw will be to the whole sustaining force, in the case of equilibrium as A B to B D; that is, as the circumference of the convex screw is to the distance between the threads when measured in a direction parallel to the axis.

But the screw, when applied as a mechanical power, is never used in its simple state; a lever or wheel is always fixed perpendicularly to the axis, and the moving or sustaining power is applied near the outer extremity of the lever, or at the circumference of the wheel. In this last case, the ratio between the moving-power and the resistance is as the distance between the threads of the screw is to the length of that circumference; and the velocity of a point on the axis is to that of a point on the circumference in the same ratio. The friction of a screw is however very great, and is frequently equal to, at least, the weight supported, for it will prevent that weight from descending when the moving-power is taken away.

An *endless* screw consists of two or more spiral fillets or threads on a rod which is capable of being turned on its axis by a power applied to the handle of a winch, or to a string passing over the circumference of a pulley attached to the rod. The threads work between teeth on the circumference of a wheel, so that while the revolution of the rod continues, the wheel turns on its own axis. If the radius of the winch or of the pulley on the screw-rod be 6 inches, and the distance between the threads of the screw be 1·10th inch, a power represented by unity at the circumference of the pulley will be in equilibrio, omitting the effects of friction, with a resistance expressed by $6 \times 10 \times 2\pi$, that is, by 376·99 (π being the half circumference of a circle whose radius is unity) applied at the threads of the screw or at the circumference of the wheel.

If the lines A F, C H, &c., were drawn on paper, and that paper were bent on the surface of a convex or concave cylinder, one spiral thread would be formed by the union of A F, E K, &c., at their extremities, and another by the like union of C H, G M, &c.: this is called a double-threaded screw, and it is evident that its mechanical power depends upon the ratio of A B to B F, while that of the single-threaded screw depends on the ratio of A B to B D; that is, with apparently an equal distance between the threads on both screws, the power of the latter is double that of the former.

From the high ratio which the resistance bears to the moving-power in the screw, the use of this machine for moving or compressing bodies is very great; it is also extensively employed in the construction of philosophical instruments for measuring small angles or distances. [MICROMETER.]

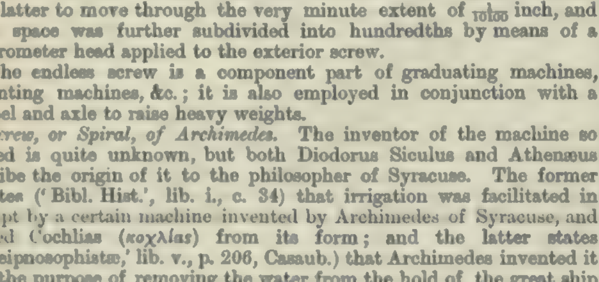
The ingenious screw-machine which was invented by Mr. Hunter, and is described in the 'Phil. Trans.' vol. 17, consists of one convex screw which works in the interior of another convex screw. The latter works in a concave screw which is fixed; and the former is capable of moving in a rectilinear direction only, being prevented from turning on its axis with the rotation of the exterior screw. Also the number of threads in an inch on the convex surface of this last is less by one than the number in an inch on the convex surface of the other: suppose the first number to be 10 and the other to be 11; then one revolution of the exterior screw would cause the whole machine to move forward through a space equal to $\frac{1}{10}$ inch, but in the same time the interior screw is carried backward through $\frac{1}{11}$ inch. Therefore the forward motion of this last is equal to $\frac{1}{10}-\frac{1}{11}$, or $\frac{1}{110}$ inch; and to produce an equal effect in a simple screw, the latter should have 110 threads in an inch.

Mr. Barlow of Woolwich mentions a compound machine of this kind in which the exterior screw had 100 threads in an inch, and the interior screw 101 threads; therefore one turn of the machine caused the latter to move through the very minute extent of $\frac{1}{10100}$ inch, and this space was further subdivided into hundredths by means of a micrometer head applied to the exterior screw.

The endless screw is a component part of graduating machines, counting machines, &c.; it is also employed in conjunction with a wheel and axle to raise heavy weights.

Screw, or Spiral, of Archimedes. The inventor of the machine so called is quite unknown, but both Diodorus Siculus and Athenæus ascribe the origin of it to the philosopher of Syracuse. The former relates ('Bibl. Hist.', lib. i., c. 34) that irrigation was facilitated in Egypt by a certain machine invented by Archimedes of Syracuse, and called Cochlias (*κοχλίας*) from its form; and the latter states ('Deipnosophistæ,' lib. v., p. 206, Casaub.) that Archimedes invented it for the purpose of removing the water from the hold of the great ship which was built by King Hiero of Syracuse. Vitruvius ('De Architectura,' lib. x., c. 11) describes the machine under the name of cochlea. He says that it consisted of four or eight laths bent spirally, and fixed at one edge against the axle, so as to form as many winding channels about it; and that the whole was covered by a cylindrical case, formed of planks, nailed over the exterior edges of the laths. The lower extremity was immersed in the water, which, rising along the channels by the revolution of the machine on its axis, was discharged at the upper extremity. Vitruvius adds that it was turned by men walking on its outer circumference, probably on the conical surface of a bevelled wheel fixed to the axle.

By the account which Vitruvius has given of its disposition, the spiral laths were placed nearly at an angle of 45° with the axle, and the latter was inclined to the horizon in an angle of 36° 52′. The cause of the ascent of the water, and the limits of the inclination of the axle to the horizon, will be seen from the following details which refer to the modern form of Archimedes's spiral as it is also called. It may consist of either a flexible tube open at both ends and wound spirally on the exterior surface of a cylinder; or it may be a plate of metal coiled about an axis, like the threads of a screw, and enclosed within a hollow cylinder so as to be completely water-tight. The machine is fixed in an inclined position, with its lower extremity immersed in the water which is to be raised. While it is at rest the water occupies the lower part between two of the threads or bends of the spiral, at bottom; but, when turned on its axis, this part of the machine being made to ascend, the water will by its gravity be caused to descend into the lower part between the next bends of the spiral, while in reality it rises, with respect to its former position, in consequence of the rotation of the tube, or bends, within which it is contined. Thus the water continually proceeds towards the upper part of the machine, from whence it is discharged into a reservoir placed to receive it.



It is shown, by writers on hydraulics, that this machine cannot raise water when the angle which a line drawn centrally on the spiral bends makes with planes parallel to the base of the cylinder is greater than the angle which the latter makes with the horizon; and it is recommended that, in practice, the angle which the axis of the cylinder makes with the horizon should be between 40 and 60 degrees. Such a machine is particularly useful when the water is mixed with gravel, weeds, and the like, which would spoil the action of a common pump. For computations concerning the force requisite to turn the machine, and the quantity of water which it will raise in a given time, see Gregory's 'Mechanics,' vol. ii.

A machine consisting of a pipe wound spirally about the surface of a cylinder, or cone, which is made to revolve about its axis when the latter is in a horizontal position, is called a *spiral-pump*. At one extremity of the spiral, water and air in nearly equal quantities being allowed to enter, the former will, in consequence of the revolution, be forced up an ascending pipe which may be attached at the other extremity.

The Archimedian screw has been occasionally employed in modern times to raise water from docks, basins, &c.; and it might be used to raise globular bodies, as cannon balls, from one level to a higher, as from the hold of a ship to the top of a wharf. A similar machine, having the spiral detached from and revolving within the cylinder which is about it, is also used. It is said to raise more water than the usual screw, but it cannot be elevated at a greater angle with the horizon than 30°, and its action is more easily impeded by the sand or gravel which is frequently mixed with the water.

For the application of the screw to navigation, we must refer to STEAM NAVIGATION.

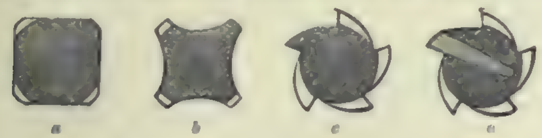
SCREW-JACK, a portable machine for raising great weights by the agency of a screw. Portable jacks, which are sometimes worked by a rack and pinion instead of a screw, are used for raising heavy carriages; the head of the jack being placed under the carriage, and raised by turning the screw with a lever. The "Universal Screw-Jack" is a great improvement on the common machine, as it allows lateral as well as vertical motion. In it the nut in which the vertical screw works is fixed in a carriage resting on the framework that forms the base of the machine, and capable of being moved upon it by means of an horizontal screw turned by a ratchet lever. This kind of jack is particularly useful on railways, where it affords a simple means of lifting a carriage or engine that may have run off the rails, and then moving it laterally until the wheels are in their proper position over the rails.

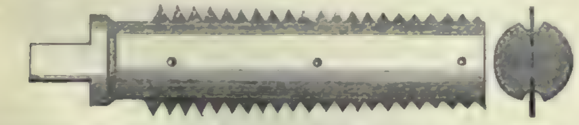
SCREW MANUFACTURE. The blanks for ordinary screws are sometimes made of round rolled iron, cut into the required lengths, and pinched when red-hot between a pair of dies in the chaps of a vice; while the heads are formed with a hammer, or the stamp of a fly-press. Another plan is to form the blanks of iron wire, cut by a machine, and have the heads struck up in a die without the application of heat. After forming the head, the next process is filing or turning the necks and heads in a lathe; after which the nick, or groove to receive the end of the screw-driver, is cut with a circular saw. The cutting of the worm is sometimes performed in a lathe, the blank being fixed in a chuck, and projected during its revolution between a pair of stationary cutters; the longitudinal motion of the blank, and the inclination of the thread, being determined by a regulating or pattern screw attached to the mandril. Small screws are frequently wormed by a similar apparatus turned by a winch-handle attached to the mandril; and sometimes by means of a steel tap-plate. In another plan the worm is formed by means of a pair of stationary cutting dies; between which the blank is projected by an apparatus which gives it an alternating rotatory motion. The dies themselves regulate the size of the thread, without the use of a pattern screw, and they must therefore be changed for every variety of screw. The best screws are made to taper slightly from the head downwards.

Several attempts have been made to produce screws by *casting*. In the ordinary method, the chief obstacle in the way of casting screws consists in the difficulty of removing the pattern from the mould. Mr. Maullin has devised a method of overcoming this difficulty by an apparatus for *screwing* the patterns (of which a great number might be used together) out of the mould, so as to leave the impression of the thread uninjured.

Screw-bolts and other screws for working in metal are manufactured in a similar manner to those for working in wood, when the number required is sufficient to justify the expense of adjusting the machinery. When this is not the case, they are, if small, often cut by hand, without the aid of a lathe. The die, or instrument for cutting an external screw, resembles a common nut, but is usually divided into two parts, which are fitted into an iron stock or die-frame, with long handles. Notches are cut in the die, across the direction of the threads, in order to produce cutting angles, and to afford room for the escape of the portions of metal removed in cutting the worm. The die, which is formed of steel, and well tempered, is inserted in the die-stock, with its two halves a little distance apart, but capable of being brought together by regulating screws fixed in the die-stock. The bolt to be made into a screw is fastened in a vice, while its end is placed in the die. The operator then proceeds to turn the die-stock, so as to worm the die on to the bolt; not by a continuous motion in one direction, but by a series of turns backwards and forwards. When the die has proceeded as far as the worm is required to extend, it is taken off, screwed up a little closer, and again applied in the same manner; the process is repeated, closing the die a little after each operation, until the worm is cut to the required depth. In working a similar apparatus by machinery, the dies are sometimes made in four pieces, the die-frame is stationary, and the bolt or screw-pin itself revolves. In this case the rotation is continuous, but in other respects the operation resembles that described. In cutting large screws, especially with a square thread, a steel cutter is sometimes used with the die, whether tufned by hand or fixed in a lathe. Very small metal screws are cut by a steel tap-plate, wormed and notched in a similar manner to the dies above described, but having several holes varying slightly in size; the worm being formed progressively, by using at each operation a smaller hole than at the preceding one.

Hollow or interior screws are commonly cut by means of a steel tap, which is simply a screw of which great part of the worm is removed by filing flat faces along its whole length, the angles left by this operation forming a series of obtuse cutters. The head of the tap is squared, to fit into the middle of a long handle, by which it can be turned with considerable purchase. The taps for cutting screws in wood are commonly fluted on the sides, to make them cut the more readily, and to afford more room for the escape of the cuttings. The tap invented by Mr. Jones answers the purpose of a tapering tap for commencing the screw, and a cylindrical one for completing it: the lower part being tapered, while the upper is left cylindrical. The tap is shown at *c*, more adapted for cutting than either *a* or *b*, which are the more usual forms. In large taps of this kind a steel cutter may be inserted, as shown in the section *d*, at the commencement of the cylindrical portion of the tap; the cutter being made to project a little, so that the tap follows it without difficulty. An ingenious kind of tap for cutting a square-threaded screw consists of a hollow screw of steel, having a hole drilled obliquely from the front end of the thread to the hole in the centre of the tap. The edges of this oblique hole, being made sharp, cut their way through the wood when the tap is turned round: while the hole itself forms a channel by which the cuttings escape into the cavity in the centre. For cutting internal screws in wood, where great accuracy is not required, the tap invented by Mr. Siebe, represented in the following cut, is useful. Though the wooden part is cylindrical, the steel plate tapers towards the end that enters the hole, in order that, by the first teeth projecting but little, the instrument may cut gradually. A groove is cut on each side of the tap, where the plate is inserted, to afford room for the escape of the cuttings; and the upper end of the cylinder is made flat or square for the purpose of fitting the lever by which it is turned.





The large iron screws used in vices, presses, waggon-jacks, &c., are formed by means of dies, turned with immense power by very long levers; the thread being made without cutting, by indenting and squeezing up the metal. In the ordinary method of cutting screws in a lathe, the size of the worm, or the distance between the threads, is regulated by a pattern screw, and cannot be varied from it. An ingenious machine is used in the Woolwich dock-yard for cutting a great variety of different screws from one pattern.

In making screws for mathematical or astronomical instruments, where the greatest accuracy is essentially necessary, it is especially desirable to avoid the risk of error arising from irregularities in the pattern screw, or in any part of the machinery used. The late Mr. Holtzapffel was highly skilled in this art; but Mr. Whitworth has recently carried it to a degree of refinement never before attained.

SCREW-PILE. [PILE ENGINE.]

SCREW-PRESS. This machine offers great facilities for the application of power; as the force applied may be almost infinitely multiplied by increasing the length of the lever by which it is turned, and diminishing the distance between the threads. It is also very convenient in cases where a continued pressure is required; because, in ordinary cases, the friction of the screw is too great to allow it to run back on the removal of the power by which it is turned. In the common screw-press the articles to be pressed are laid upon a stationary *bed*, forming the base of a strong frame, in the upper cross-bar or *head* of which a nut is firmly secured. The screw works up and down in this nut, and to its lower end is attached the *follower*, or moving piece which presses on the substance operated upon. The connection between the screw and this piece is such that the follower rises and falls, but does not turn round with the point of the screw; and the steady motion of the follower is provided for by making it fit closely to the side-pieces or cheeks of the press, which therefore act as guides. At the lower end of the screw there is usually a massive globular head, pierced with two holes at right-angles with each other, which receive the end of a long iron lever, by which the screw is turned. The best screw-presses are made of iron.

The great space required for turning a long lever is a serious inconvenience in some cases, and has led to the contrivance of several methods for turning the screw with great power by a more compact apparatus. In a press invented and patented by Mr. Dunn, the screw is turned by means of a short bent lever acting upon a ratchet-wheel fixed on the lower part of the screw. In another ingenious modification of the common screw-press, invented by Mr. Pouchée, a large cogged-wheel is fixed horizontally on the screw, just below the common head for receiving the end of the lever. A small pinion, having a square axis to receive a lever handle, is fixed on the platten or follower of the press, and works into the large cogged-wheel. This press is worked in the ordinary way until the screw is turned as far as the lever will conveniently move it. The bar is then removed, and the handle of the pinion put on, and by turning it the screw may be further depressed. In one form of screw-press for hot-pressing, the plates do not, as in those of the usual construction, need to be removed for heating; they being kept at the necessary temperature by hot air introduced into four hollow columns, which serve the purpose of cheeks to the press.

While the diminution of the size of the thread affords the means of increasing the power of a screw-press, it is attended by the serious disadvantage of diminishing its strength. This difficulty may be avoided by the use of a double or differential screw. The press may be made of the usual form, excepting that the lower end of the screw is cut with a finer thread than the upper part. This smaller screw is received into a nut resting on the follower, and capable of turning on it. The head for receiving the lever by which the screw is turned is in this case placed above the head or top beam of the press. When in use the nut is keyed fast to the screw, so that it turns with it; and the action is exactly the same as that of the common press. When the screw has been turned as far as it will go in this way, the key that connected the nut with the screw is removed, and the nut is keyed fast to the presser. The screw being again turned, the lower thread enters the nut, so that the presser is depressed only through a space equal to the difference between the width of the upper and lower threads of the screw. By making the two parts of the screw very nearly alike in fineness, the distance traversed by the platten may be diminished, and the pressure increased almost to infinity.

Screw-presses are occasionally made with more than one screw. In one arrangement of this kind the screws are stationary; and the nuts, which are fitted into the follower, are turned by means of cogged wheels driven by an endless screw laid horizontally on one side of the follower, and terminating at each end in a winch-handle. Mr. Brindley's press has several screws instead of one, each having a cogged wheel working into another fixed on a plain central shaft, which is moved by a winch and bevil gear.

SCREW PROPELLER. [PROPELLER.]

SCRIBES. In the article MOSES, in BIOG. DIV., this word has been used as a translation of the Hebrew word שׁוֹטְרִים, which in the authorised version is translated "officers." The word which is translated "scribe" in the English Bible is סֹפֵר, or in the Chaldee סָפֵר, meaning "a writer." It was applied to an officer of the king, or, as we should say, a "secretary of state" (2 Sam. viii. 17; xx. 25; 2 Kings xxii. 3); also to a "secretary-at-war," who had the enrolment of the soldiers under his care. (Jerem. lii. 25.) It was also used to signify men learned in the Jewish Scriptures. (Ezra vii. 6, 11.) The last was the meaning which the word came to have in the later ages of the Jewish state, or rather, as the Jews regarded all learning as contained in a knowledge of their sacred books, the word *scribe* was used to designate all men of learning. In this sense we find it in the Apocrypha and the New Testament, as the translation of the words *γραμματεὺς, νομικὸς, νομοδιδάσκαλος*, for the *lawyers* (as our version generally translates the last two words) were evidently the same persons as the Scribes. Their office was to administer the sacrifices and to explain the law. They had seats in the Sanhedrim, and were generally Levites. They, at least occasionally, wore long clothing (Mark xii. 38), which was effected by enlarging the border of their garment with a fringe. In the time of Christ they appear to have been for the most part Pharisees, but they did not form a sect.

(Winer's *Biblisches Realwörterbuch*, art. 'Schriftgelehrte.')

SCRIPTURE (γραφή, *scriptura*). This word means simply a *writing*, but it has long been used to designate the sacred books of the Old and New Testament. It is thus repeatedly used in the New Testament in reference to the Old Testament, and in one passage Peter applies it to the Epistles of Paul, and very probably he meant to include under the word some of the other books of the New Testament which were then written. (2 Peter iii. 16.) The different forms in which this word occurs in the New Testament are "the Scripture," "the Scriptures," "the Holy Scriptures," "inspired Scripture." (2 Tim. iii. 16; compare Smith's 'Script. Test. to the Messiah,' chap. ii., note A.) The term *a Scripture* is also used for a passage in the Scriptures. (Apocrypha; Bible; Canon; and the titles of the different books of the Bible.)

SCROFULA, or SCROPHULA, the technical name for the disease that is popularly called "the King's Evil:" the origin of the latter term will be explained presently; that of the former is very obscure and uncertain. We find the word *scrofula*, or rather *scrofulæ* in the plural, employed for the first time to signify the present disease, or one supposed analogous to it in cattle, by Vegetius ('De Re Veterin.', lib. iii., cap. 23, ed. Schneider). It is generally admitted to be derived from the Latin *scrofa*, or *scropha*, "a sow," although the reason of the derivation is by no means clear. The same analogy, whatever it may have been, influenced also the Greek and Arabic writers in naming the disease, as the former call it χοιρὰς, or χοιράδες; and the latter *khanázir* (Avicenna, tom. i., p. 154; l. 36, p. 194; l. 30, vol. ii., p. 73, l. 12, ed. Rom., 1593, fol; Albucasis, 'De Chirurg.,' lib. i., cap. 22, p. 50, ed. Oxon., 1778, 4to.), both of which words are intimately connected with *swine*. The classical Latin term for the disease is 'struma' (Celsus, 'De Medic.,' lib. v., cap. 28, § 7; Pliny, 'Hist. Nat.', lib. viii., cap. 77), or 'strumæ' in the plural (Celsus, lib. i., cap. 9; Pliny, lib. xxii., cap. 16), which is also a word of which no satisfactory derivation has been given, as probably few persons will agree with Dr. Good in deriving it from στρῶμα, 'congestion,' or 'coacervation,' as of straw in a litter, feathers in a bed, or tumours in the body."

The vulgar English name applied to it, namely, "the King's Evil," commemorates the virtues of the *royal touch*, to which, from the time of Edward the Confessor till the reign of Queen Anne, multitudes of persons afflicted with scrofula were subjected. A similar custom prevailed in France; and miraculous powers for the cure of scrofula were likewise claimed for different Romish saints, for the heads of certain noble families, for the seventh son, and for many consecrated springs. The *royal touch* requires some further notice. That the kings of England for several centuries actually exercised their touch for the cure of scrofulous complaints is proved by abundant historical authority; and scarcely any of our old historians, who wrote during a period of at least five hundred years, have omitted taking notice of this strange and unaccountable fact. We have not room here to give the evidence fully, and must refer those who wish to inquire more deeply into the subject to 'A Free and Impartial Inquiry into the Antiquity and Efficacy of Touching for the King's Evil,' 1722, by William Beckett, an eminent surgeon; 'Charisma, sive Donum Sanationis: seu Explicatio totius Quæstionis de Mirabilium Sanitatum Gratiâ, in quâ præcipuè agitur de solenni et sacrâ cui Reges Angliæ, ritè inaugurati, divinitus medicati sunt,' &c. &c., 1597, by William Tooker, afterwards dean of Lichfield; 'Charisma Basilicon, or the Royal Gift of Healing Strumæs, &c.' 8vo., Lond., 1684, by J. Browne; 'Several Chirurgical Treatises,' Lond., 1676, fol., and 1719, 8vo., 2 vols., by Richard Wiseman, principal surgeon in the army of Charles I., and serjeant-surgeon to Charles II., whom Haller ('Biblioth. Medic. Pract.,' tom. iv., p. 399) calls "insignis certe et peritissimus chirurgus." The question is examined at some length by Bishop Douglas, in his 'Criterion; or Miracles Examined,' &c. &c., p. 191, ed. 1754, who, while he denies the alleged miraculous powers, fully admits the reality of the cures. See also Colquhoun's 'Isis Revelata: an Inquiry into the Origin, Progress, and Present State of Animal Magnetism,' Edin., 1836, 2 vols. 8vo., who also allows (vol. i., p. 87) "the sanative efficacy of the process," but connects it with the phenomena of animal magnetism. Among the most curious parts of the subject, it may be mentioned that the old Jacobites considered that this power did not descend to Mary, William, or Anne, as they did not possess a full hereditary title, or, in other words, did not reign by divine right. The kings of the house of Brunswick have, we believe, never put this power to the proof; and the office for the ceremony, which appears in our Liturgy as late as 1719, has been silently omitted. The exiled princes of the house of Stuart were supposed to have inherited this virtue. Carte, in the well-known note to the first volume of his 'History of England,' mentions the case of one Christopher Lovel, who, in 1716, went to Avignon, where the court was then held, and received a temporary cure; and when Prince Charles Edward was at Holyrood House, in October, 1745, he, although only claiming to be prince of Wales and regent, touched a female child for the king's evil, who in twenty-one days is said to have been perfectly cured.

The history of this delusion carries with it a great lesson. It is very evident that the changed circumstances either of body or mind in which persons who submitted to the royal touch were placed produced the favourable results which have been recorded. It has been the same with popular systems of medical treatment up to the present day. The beneficial action of some agent is assumed, quite independent of any inquiry into the fact of its possessing any curative power at all, and the other circumstances by which the cured person is surrounded, which have really effected his cure, are entirely overlooked.

Scrofula is defined by Dr. Good ('Study of Med.') to be, "indolent glandular tumours, frequently in the neck, suppurating slowly and imperfectly, and healing with difficulty; upper lip thickened; skin smooth; countenance usually florid;" which agrees almost exactly with the definition given by Cullen in his 'Nosology.'

Later writers have, however, given a more extended view to the term scrofula, or scrofulous, and made it to include that general state of the system of which the indolent glandular tumour is but one symptom. The swellings and ulcerations which are so common in scrofula are found to be connected with alterations in the nutrition of the tissue of a similar kind to those which take place when tubercle of the lungs is present. [Phthisis.] Hence some writers have described a state of the whole system which they have called tuberculosis, in which either scrofula or pulmonary consumption occurs. It seems now agreed by the best pathologists that the same general state of the system which produces tubercle in the lungs produces the various forms of scrofula, including the indolent swellings of the definition of Good and Cullen. On this subject Mr. Paget, in his 'Surgical Pathology,' makes the following remarks:—"'Scrofula,' or 'struma,' then, is generally understood as a state of constitution distinguished in some measure by peculiarities of appearance even during health, but much more by peculiar liability to certain diseases, including pulmonary phthisis. The chief of these 'scrofulous' diseases are various swellings of lymphatic glands, arising from causes which would be inadequate to produce them in ordinary healthy persons. The swellings are due sometimes to mere enlargement, as from an increase of natural structure, sometimes to chronic inflammation, sometimes to more acute inflammation or abscess, sometimes to tuberculous disease of the glands. But, besides these, it is usual to reckon as 'scrofulous' affections certain chronic inflammations of the joints; slowly progressive 'carious' ulcerations of bones; chronic and frequent ulcers of the cornea, ophthalmia attended with extreme intolerance of light, but with little, if any, of the ordinary consequences of inflammation; frequent chronic abscesses; pustulæ, cutaneous eruptions frequently appearing upon slight affection of the health or local irritation; habitual swelling and catarrh of the mucous membrane of the nose; habitual swelling of the upper lip.

"Now these and many more diseases of the like kinds are amongst us, both in medical and in general language, called scrofulous or strumous; but though many of them are often coincident, yet it is very difficult to say what all have in common, so as to justify their common appellation. Certainly they are not all tuberculous diseases. Little more can be said of them than that, as contrasted with other diseases of the same forms and parts, the scrofulous diseases are usually distinguished by mildness and tenacity of symptoms; they arise from apparently trivial local causes, and produce, in proportion to their duration, slight effects; they are frequent, but not active. The general state on which they depend may be produced by defective food, with ill ventilation, dampness, darkness, and other depressing influences; and this general state of constitution, whether natural or artificially generated, is fairly expressed by such terms as 'delicacy of constitution,' 'general debility,' 'defective vital power,' 'irritability without strength.' Such terms, however, do not explain the state that they express; for they all assume that there are in human bodies different degrees of vital power, independent of differences of material, which is at least not proved.

"Such is the vagueness of 'scrofula' and of the terms derived from it as commonly used in this country. They include some diseases which are, and many which are not, distinguished by the production of tuberculous matter. It has been proposed, but I doubt whether it be practicable to make 'scrofulous' and 'tuberculous' commensurate terms; as at present generally employed the former has a much larger import than the latter. The relation between the two is, that the scrofulous constitution implies a peculiar liability to the tuberculous diseases and they often co-exist. These differences are evident in that many instances of scrofula (in the ordinary meaning of the word) exist with intense and long continued disease, but without tuberculous deposit; that as many instances of tuberculous disease may be found without any of the non-tuberculous affections of scrofula; that as Mr. Simon has proved, while the diseases of 'defective power' may be experimentally produced in animals by insufficient nutriment and other debilitating influences, the tuberculous diseases are hardly artificially producible; that nearly all other diseases may co-exist with the scrofulous, but some are nearly incompatible with the tuberculous.

"Now whether we disuse or still use in its vagueness the term 'scrofula,' we may make a group of the 'tuberculous' diseases, defined by the peculiar morbid product of which I have described the chief characters. Only at present we must be content, I believe, to be sometimes in doubt whether the substance found in lymphatic glands and commonly known as scrofulous matter be truly tuberculous matter or degenerate lymph or pus."

In the case of glands affected with what is called scrofulous inflammation, the same peculiar exudation is observed as is found in the lungs of those who are affected with phthisis.

This exuded matter generally presents a yellowish or dirty-white colour and varies in consistence from a substance resembling cheese to that of cream. It is sometimes soft in one place and hard in another. It also presents itself in masses of various sizes, from a millet seed to a hen's egg. It is friable on pressure and may break down into a pulpy matter. If a small piece is squeezed between two pieces of glass and placed under a microscope it presents a number of irregular-shaped bodies, varying from the $\frac{1}{3000}$th to the $\frac{1}{1200}$th of an inch in diameter. These bodies contain from one to seven granules, and are unaffected by water, but rendered transparent by acetic acid. These have been called tuberculous corpuscles. They are surrounded with minute points or granules, which are more abundant in the softer tuberculous matter. These corpuscles are often accompanied by deposits of mineral matter, consisting of phosphate and carbonate of lime. They occur, for the most part, in young persons, and may occur in any part of the body; but they are most frequent in the lymphatic glands. After these parts the fibrous textures are most frequently attacked, as the lungs and serous surfaces. These exudations are very slow in their progress, and are thus distinguished from the exudation of ordinary inflammation. They exhibit little or no tendency to the production of perfect cells or normal tissues, and the cells are slowly formed and slowly break down. They have little tendency, when once formed, to absorption; but show a great tendency to breaking up and ulcerating.

Scrofula, though not a contagious disease, is unquestionably hereditary; and hence very generally dependent upon a peculiar diathesis. Yet, like many other hereditary diseases, it is also occasionally generated as a primary affection, without any hereditary taint that can be discovered. When it occurs as a primary or ingenerated affection, it is by no means always limited to any particular temperament or habit of body. But where scrofula appears hereditary, and especially where it does not show itself very early, it is often accompanied with a peculiar constitution. "The character of a scrofulous child," says Sir Astley Cooper, "is as follows:—You will find the skin thin, if you pinch it, which is quite different from the skin of children who are not scrofulous; in them the skin is solid and dense, and the fibres strong; but in scrofulous the skin is thin, and the vessels may be seen meandering under it; and it is on this account that persons with this disease frequently have a rosy colour, arising from the thinness of the skin, which allows the vessels to be seen under it. The hair is also light coloured. If you observe, in a family of five or six children, one among them who has a delicate thin skin, with light hair and complexion, you will find that if they are all exposed to the same causes, they will escape from any scrofulous affection, with the exception of the one stamped by nature, and that this, during its growth, will be affected by the disease. The hair is also extremely fine, the eyelashes long, the pupils dilated, and the fingers are what is called clubbed, similar to the fingers in phthisical persons, that is, they are extremely long and thin, but at the extremities are broad and flat. The upper lip is of considerable thickness, and this is a mark of debility."

In considering the causes of a disease so deeply rooted in the constitution as scrofula is universally acknowledged to be, it is necessary to direct our attention to circumstances very remote in the history of those who are its subjects. The foundation of a scrofulous habit is frequently laid during the fœtal state, by the transmission of that peculiar organisation of the frame from parents who themselves possess it. Scrofula is also observed to originate in the healthy offspring of healthy parents, under certain circumstances, the principal of which are habitual exposure to cold and damp, privation of free air and light, and want of healthful exercise. A moist, cold, and variable climate, like that of Great Britain or Holland, is particularly favourable to the development of scrofula; in proof of which it is sufficient to adduce the great prevalence of the malady in both of those countries. A very cold or a hot climate, on the other hand, serves rather to protect us against scrofula; the former, dry and bracing, invites to exercise, and promotes digestion, and thus strengthens the system; while the latter favours the excretions, particularly that of the skin, and preserves the body from those sudden changes of temperature which in our island so often lay the foundations of scrofulous affections. Among the causes which appear to give rise to scrofula in children, are the practices of rearing them by the hand and suckling them too long; two extremes, both of which often lead to the same result,—the imperfect nourishment of the child. Another cause of this disease is confinement in ill-ventilated apartments; for the deficiency of pure atmospheric air cannot be long endured, especially during youth, without the most injurious consequences. Acute diseases, especially those accompanied with cutaneous eruptions, as small-pox, measles, and scarlet-fever, are often observed to have the effect of producing the development of scrofula; and the more tedious

the convalescence, the more frequently do symptoms of this disease ensue.

The treatment of scrofula divides itself naturally into the preventive and curative. With regard to the former, it must be applied both to those who have a scrofulous tendency and those in whom it has not yet been developed. The progeny of scrofulous parents require the greatest care and attention, if an outbreak of some form or other of the disease is to be avoided. All writers on this subject recommend that the children of scrofulous parents should not be suckled by a scrofulous mother, and that a healthy wet-nurse should be secured. Where this is not possible, it is perhaps better for the child to take its mother's milk than to rear it by hand, attention being paid to the health of the mother during the suckling of the child. In the preventive treatment of scrofula it should be recollected that cold, moisture, bad or deficient food, and impure air, are the great factors of the tuberculous deposits. Children and adults should be warmly dressed, and no exposure to cold should be allowed unless under circumstances where the reaction of the system can be secured. Thus cold bathing and exercise in the cold air are commendable as long as the natural heat is kept up. A moist and cold atmosphere acts most unfavourably. Climates that are dry, and gravelly and chalk soils, are preferable to moist climates and clay soils. The food of those predisposed to scrofula should be nutritious. It should especially abound in the oleaginous element. Children should not be allowed to reject fat, and the taking butter, cream, and fatty food, where positive indigestion does not interdict, should be encouraged. Exercise regular and constant in the open air should be taken every day. This should be sufficient to employ the muscles, to increase the capillary circulation, to promote the function of the skin, and maintain healthy nutritionary change. Of all the causes of scrofula that of impure air from overcrowding and imperfect ventilation is the most constant and prevalent. It presses most heavily on the poor, because they cannot prevent it, but the more opulent suffer from it from their ignorance of its existence. Close rooms, beds with curtains, rooms lighted with gas, crowded assembly rooms, and places of worship, all contribute to bring on a state of the body from which there is too often no escape when once it comes on. In this respect the whole of the internal arrangements of the majority of houses in our towns and cities require reform. It is not till this subject is thoroughly understood by the great mass of the community, that the devastations of scrofula amongst our city populations will cease.

The *curative* treatment of scrofula may be divided into *constitutional* and *local* applications. With respect to the former, it would be impossible here to notice all the numerous remedies that have been recommended for the cure of this disease; we must be content with pointing out those that are most generally esteemed. Of all the remedies employed in the treatment of scrofula, perhaps none have enjoyed a greater reputation than mercurials; but it is only from their purgative and alterative effects that they prove beneficial, and not when they produce that powerful influence on the frame which so rarely fails to ensue from their free exhibition. Tonics are amongst the most valuable remedies; of these, cinchona is perhaps the most efficacious, and from the concentrated form in which it can now be exhibited (namely, the disulphate of quina), the most generally available. Other vegetable tonics and bitters have been administered with advantage in scrofula, such as calumba, gentian, and hop. Of the metallic tonics used in scrofula, iron is that which has been found the most beneficial; and the best forms of exhibiting it are the Vinum Ferri, the Tinctura Ferri Sesquichloridi, and the Ferri Sesquioxidum, in powder. Iodine, as prescribed by Lugol, is at present in considerable repute. It is successfully employed both internally and locally, in each of which modes it increases the action of the absorbents; and in the latter it likewise often induces suppuration of strumous tumours, and thus hastens their removal. Allusion has been made to the use of fatty food as a preventive of scrofula, and cod-liver oil has been found of no less value as a medicine. It may be combined with any other medicines or system of treatment that may be thought necessary. The evidence in favour of its use in most forms of scrofula is so decided, that it never ought to be overlooked as part of any general system of treatment. The use of baths in the treatment of strumous affections is of great value, the kind of bath to be made choice of being determined by the existing state of the patient. Sudden immersion in cold water, and especially sea-water, has long been an approved remedy in scrofula; but when the strength of the patient is so reduced that no kindly glow follows, and when there is decided feverishness, the cold plunge-bath is not admissible. In most cases the warm-water bath, and still more that of vapour, will be found highly soothing and restorative.

With respect to the *local* treatment, indolent scrofulous tumours, when the health is little reduced, may be dispersed or made to suppurate by continued pressure or by blistering, which can be employed when the situation of the swelling will not admit of pressure. In the treatment of scrofulous ulcers, the simplest and mildest dressings answer best. Cold spring water is a favourite application with many practitioners; and preparations of lead are, upon the whole, very convenient and useful applications, provided the solutions be used in a state of sufficient dilution to prevent irritation. Formerly, the extirpation of scrofulous tumours was advised, but this method is now considered as being for the most part injudicious and unnecessary, with the exception of diseased joints and a few other parts which frequently require being amputated for the sake of saving the patient's life. Caustics have been employed for the same purposes, instead of the knife; but as they effect the object in view less certainly, more painfully and tediously, and cause extensive ulcers, they are disused by all the best surgeons of the present day. Some authors advise making issues, and keeping them open, in order to prevent any ill effects from the healing of the scrofulous ulcers. Issues may perhaps be unnecessary for any purpose of this kind; but they are eminently useful as a part of the local treatment of scrofulous joints and abscesses. When all hope of recovering a diseased portion of the body is at an end, the question immediately presents itself whether such part ought not to be removed by an operation. In considering the propriety of amputation, it is necessary to determine how far the continuance of the affections brings the patient's life into hazard, and whether he has still sufficient strength left to undergo the operation. When another important joint, or a vital organ, as the lungs or bowels, is already the seat of incurable disease, such operation is nugatory, and in such cases unquestionably it should not be performed. Great caution however is required in making our final decision; for every practitioner of experience has seen instances where the symptoms of visceral disease appeared almost to preclude hope, and yet have yielded on the removal of the local irritation, and a cure has been the happy result.

(Cooper, *Surg. Dict.*; *Cyclop. of Pract. Med.*; Ancell, *Treatise on Tuberculosis*; Dr. Bennett, *Principles and Practice of Medicine*; Paget, *Surgical Pathology*; Lugol *on Scrofula*, by Dr. Rankin; B. Phillips, *On Scrofula and its Treatment.*)

SCRUPLE (*scrupulum*, diminutive of *scrupus*, a term for a sort of pebble, probably used in counting) is now used only as the third part of a dram, or the 24th part of an ounce, in the apothecaries' division of the troy pound. It was used originally as the 24th part of the Roman uncia; afterwards as the sixtieth part of an hour, or what is now called the minute. The sixtieth part of a minute was called scrupulum secundum, the sixtieth part of a scrupulum secundum was scrupulum tertium, &c., whence our terms second, third, &c. applied to the sexagesimal divisions of the minute. It is worth noting that the ancient form of the word is also scripulum and scriptulum, which might suggest a different derivation of the word as a weight or measure. It may be worth while to add, that the scrupulum is described by lexicographers as a small pebble, such as found its way between the sandal and the foot, whence the use of the word to denote a difficulty or objection.

SCUDO. [MONEY.]

SCULPTURE, in its strict sense, is the art of carving or cutting any material into a proposed form or shape. In its more general acceptation it is the art of representing objects by *form*; and is thus applied to carving, modelling (or the plastic art), casting, whether in metal or other materials, and to gem-engraving. Sculpture is practised in various ways; namely, in forming entire or insulated figures, as statues or groups, called in technical language, "the round;" or in representing objects more or less raised without their being entirely detached from a background. This latter is termed "relief," and the degrees of relief are defined by modern writers and artists by the expressions *alto-rilievo*, when the object is so salient as to be nearly "round;" *basso-rilievo*, when it is slightly raised from the background; and *mezzo-rilievo*, when a medium is preserved between the extremely high and the very flat "relief." There is another variety of this manner of working "basso-rilievo," which is only or chiefly found in Egyptian sculpture; the outline is sunk into the plane or ground, and the parts are then formed and rounded on the principle of basso-rilievo. By this mode of working there is usually no projection beyond the profile or face of the original ground; to gain effect therefore in this kind of *relieved intaglio*, the Egyptian artists frequently painted the sculpture.

It is not necessary to enter into a discussion of the various opinions respecting the comparative antiquity of the arts of painting and sculpture. Pliny's story ('Hist. Nat.,' xxxv. 12) of the daughter of Dibutades having traced the outline of her lover's profile on the shadow cast on the wall, and of this outline being afterwards filled in with clay by her father, would give the priority to drawing; and it seems obvious that drawing an outline must be antecedent to modelling, or cutting in *relief*; but a little consideration will suffice to establish the probability that *insulated* objects and figures were made in the very earliest times. So many materials offered themselves upon which the imaginative faculty could be exercised, that there can be little doubt that rude attempts at forming clay, or any other plastic substance, into a defined shape, were amongst the first exercises of human ingenuity; and the easy task of thus repeating or copying the real form of an object, compared with that of representing by lines (and on a flat surface) its partial and perspective appearance, is quite sufficient to lead to the inference that this was the earliest mode of imitation. The ancients appear to have availed themselves of every known material that was capable of being employed in sculpture. Pliny, Pausanias, and other writers supply some curious information on this subject, for, in describing works of art, they usually mention the materials in which they were executed.

For modelling, clay, wax, and stucco, or plaster, appear to have been universally adopted; and works of great antiquity formed of these substances, are still preserved. The clay model was usually baked, by which it acquired a hardness scarcely inferior to stone. Moulds were also made of clay, and being subjected to the above process, were safely used as forms into which softer substances could be pressed, and thus objects were multiplied without difficulty. The almost countless number of figures, bassi-rilievi, lamps, tiles, architectural ornaments, vases, domestic utensils, stamps, &c., which are found of this material (called *terra cotta*, baked earth), proves the extent of its employment in the earlier ages of art. The objects usually composed of terra-cotta are of small dimensions, but there are instances of its being used for works of considerable size. In the Museo Borbonico at Naples are two statues, of Jupiter and Juno, above six feet high, and two others, one of an actor and the other an actress, above four feet high. They were found at Pompeii. The larger figures are inferior in their forms to the others, but whether the faults of proportion arise from the shrinking or contraction of the clay in baking, or were errors in the original modelling, it is not easy to determine. The specimens of *terra-cotta* preserved in England are for the most part of small size; but there are some very beautiful objects, both for execution and subject, in the Townley collection of the British Museum. It appears highly probable that the ancients always, or almost always, painted their *terra-cotta* works. In many instances the colour still remains, and the draperies of figures, and portions of architectural ornament, often exhibit well preserved designs of border patterns. The employment of wax for modelling and casting can be traced to a very remote period. The Romans also employed it for making statues, or perhaps only busts. It was a custom in some families to preserve portraits of their ancestors made of wax. [PORTRAIT.]

A great proportion of the ornamental work, rilievi, &c., in the buildings of Pompeii is of *stucco* or plaster. Few collections of antiquities are without specimens of figures and ornaments modelled in this material. Some in the British Museum are examples of great delicacy and sharpness of execution. Many of them are painted; red is the prevailing colour.

The list of materials used for *carved* works comprises every substance, hard or soft, that could by possibility be employed for the purpose, including porphyry, basalt, granite, marble, alabaster, ivory, bone, and wood of all kinds. The three first named were used chiefly by the Egyptians, who seem, in all their monuments of art, to have worked with the view of securing the durability of their productions, employing, whenever they could do so, and especially for works of importance, materials likely to resist the action of the atmosphere. When the introduction of some of the superstitions of Egypt into Rome led to the adoption of the Egyptian style of sculpture, it became the fashion to execute works of art in the above materials; but this did not occur till the reign of Hadrian, before and after which time they are seldom met with.

The variety of marbles known and used by the ancients is almost infinite. (Pliny, 'Hist. Nat.,' xxxvi. 7.) Those preferred for their superior texture, colour, or applicability to sculpture, were, first, the Parian, which was found in the island of Paros. It is called also Marpessian, from the mountain from which it was brought; and sometimes Lygdinum or Lychneum, perhaps from its bright sparkling appearance. In the second rank was the Pentelic marble, which was procured from Mount Pentelicus, in the neighbourhood of Athens. It was highly esteemed by the sculptors of antiquity. Its colour, like that of the Parian marble, is white; but it usually has a cold bluish tone, arising from the grey, and sometimes greenish, streaks that run through it; while the general hue of the marble of Paros is warm and creamy. The Italians often called the Pentelic marble *marmo salino*, from the salt-like appearance of its grain or crystals. The marble of Mount Hymettus in Attica was also much esteemed; it resembled in colour the Pentelic. After the conquest of Greece by the Romans, this marble was imported in great quantities into Italy. Lucius Crassus introduced it most extensively in the decoration of a palace which he built on the Palatine; an instance of unusual luxury, which was much reflected upon at the time. The marble of Thasos seems to have been much used, especially for architectural purposes. It was employed for covering and encasing edifices, and for lining reservoirs and fish-ponds. The Italian marble was procured from Luna, in the range of mountains near which are the modern towns of Massa and Carrara. These quarries seem to have been unknown till about the time of Julius Cæsar, when they were extensively worked. The grain of the Carrara marble is finer than that of the Greek marbles above mentioned. Its colour is usually a rich white, and it bears a close resemblance to fine lump sugar. It is seldom found quite pure; veins and spots of black, grey, and red and yellow (oxides of iron) occur in it. The Romans also worked quarries in Africa which produced limestone and white marble with veins of pale grey. The quarries in Greece are no longer worked, and the chief, or it may be said, the only supply of statuary marble is at present from Italy. These were the principal white marbles which were employed by the sculptors of antiquity, and in which some of the finest remains of art are executed.

Among the varieties of wood in which objects were carved, we find oak, cedar, cypress, sycamore, pine, fig, box, and ebony. Cedar was thought to be very durable, and on that account was used, Pliny says, for images of the gods; the same author especially distinguishes cypress, cedar, ebony, and box, for their capability of resisting the injuries of time. (Plin., 'Hist. Nat.,' xvi. 40.) Pausanias saw several statues of wood during his travels in Greece, and the following instances will serve to show that this apparently humble material was employed for representing the most elevated personages in the ancient mythology. The statue of Apollo Archegetes was composed of ebony, as was the statue of Diana Limnitis. At Lacedæmon the statue of Venus was of cedar. A statue of Apollo made of box adorned the treasury of the Sicyonians in the Altis. In the temple of Castor and Pollux at Argos were their statues, those of their children, and of their mothers, all made of ebony. All these works in wood have perished, notwithstanding Pliny's observation, "Materiæ ipsæ æternitas" ('Hist. Nat.,' xiii. 5). A few however of smaller dimensions have been found in tombs. They are chiefly figures of Egyptian idols; and the wood of which they are made seems to be sycamore. Gold, silver, iron, tin, copper, lead (and their compounds), wax, and plaster, were all used for the purpose of *casting*. [BRONZE; FOUNDING.] A mixture of gold and silver, in the proportion of one to five, formed a composition termed *Electrum*. According to Homer, Helen presented to the temple of Minerva at Lindus, in Rhodes, a cup made of electrum, of the exact form and size of one of her own breasts. A mixture of copper and tin, with sometimes, but not always, small portions of other metals, formed what the Greeks called *Chalcos* (χάλκος); the Romans, *Æs;* and modern artists (from the Italians), *Bronze*.

There was a statue of Augustus of *amber;* and at the celebration of funeral ceremonies, as those in honour of Sulla, statues were sometimes made of *gum* and *aromatics*, as well as of other materials of the most combustible nature, as, for instance, of *hay*. Among the strange conceits of artists there is mention of a statue of the goddess of Love made of *loadstone*, which attracted a Mars of *iron*.

The union, or rather, combination of different marbles in the same work was called *polylithic* sculpture. When painting or colouring was resorted to, it was termed *polychromic* sculpture. These mixtures, which modern taste disapproves, were resorted to by the most celebrated artists of antiquity, and during the most flourishing period of sculpture and architecture in Greece. The various architectural members of their temples were picked out in red and blue; and the backgrounds, and frequently parts also of the sculpture itself, especially of rilievi, were coloured, to give further effect to the design. There can be no doubt that the peculiar circumstances of the climate must materially affect the appearance of this kind of decoration. What in the dull atmosphere of northern countries would, at the best of times, appear either dingy or tawdry, might easily be imagined to have a very different effect when seen clearly defined and relieved against a cloudless blue sky, and by the bright glare of a southern sun. The combination, under such favourable circumstances, of white marble, of which the temples were usually constructed, with simple though brilliant colours to indicate the mouldings or smaller members of the architecture and sculpture, sparkling with gold ornaments, certainly offers to the fancy a spectacle of surpassing splendour. It is not quite so easy to reconcile with *our* notions of propriety or good taste the mixture of materials for sculpture *within* buildings, where space, and sometimes light, if the temple were not open in the roof, would be wanting to dissipate the heaviness of effect which it is conceived such works would have. The introduction of foreign substances, either metal, precious stones, paste or glass, for eyes in statues and busts (of which examples occur in works even of the best period of art), is a species of barbarism that is quite unaccountable, and which the most zealous admiration of the genius of the Greeks cannot qualify or excuse. Such instances may however be considered exceptions to the rule of pure taste and simple feeling which is exhibited in the greater number of works by the sculptors of Greece; and modern experience will probably afford the best solution of what would otherwise seem an anomaly, by suggesting that the artists, even of those times, were occasionally dictated to, and their own better taste overruled by the caprice of their employers. It seems difficult to account otherwise for the strange circumstance of the lips as well as the eyes being inlaid. There is more than one example of this among the fine bronzes preserved at Naples.

Inscriptions were sometimes inserted into bronze statues; the letters being of a different metal from the figure. Cicero ('In Verr.,' Orat. iv.) speaks of an Apollo inscribed with the name of Myron. In the collection at Paris is a statue of a youth in bronze, on the left foot of which are the remains of two Greek words, ΑΘΑΝΑΙΑ . ΔΕΚΑΤΑΝ, in silver letters.

There was a very peculiar combination, rather referred to than described by ancient authors, by which shades or tints of colour were produced. Plutarch ('Symp.,' lib. v.) says that the sculptor Silanion made a statue of Jocasta, the wife of Laius, king of Thebes, in which she was represented dying. To increase the intensity of the expression of the countenance, the artist by an ingenious mixture of the metals of which the statue was composed, had produced a pallid appearance. This, he says, was effected by the addition of silver. Callistratus admires a bronze statue of Cupid by Praxiteles, for its elegant position, for the arrangement of the hair, its smile, the fire in its eyes, and, he adds, there was in its countenance a vivid blush. He observes the same thing, and with equal admiration and astonishment, of a statue by Lysippus. After describing the work generally, he says, the cheeks were coloured like the rose, and those who saw it were struck with surprise at seeing the bronze imitate the appearance of nature. The same remarkable effect is noticed in a bronze statue of Bacchus by Praxiteles. To these may be added a statue of Athamas at Delphi, mentioned by Pliny. He was represented sitting after the murder of his son Learchus, whom he had precipitated from a rock. This work, he says, was not entirely of iron; for the artist, Aristonidas, wishing to express the effect of confusion and remorse in the countenance of the king, used a mixture of iron and bronze, which should imitate in some measure the blush of shame. (Plin., 'Hist. Nat.,' xxxiv. 14.) Other notices might be quoted of this practice of the ancients. The writers who refer to these effects describe them as the result of study and intention on the part of the artists, and do not allow us to suppose that the mere accident of oxidation and decomposition produced them. The art seems to be quite distinct from that called *toreutic;* the latter being the union of distinct materials, easily removable, while the former is described as effecting an amalgamation which produced shades or tints. The few writers who speak of it are certainly general in their observations, and give no technical details of the manner of effecting these combinations; but this hardly justifies the entire rejection of their testimony as to what they saw. It is most probable that they coloured the statues after they were cast, as Pliny says was done in Egypt (xxxiii. 9). The different compartments and objects in the shield of Achilles ('Iliad,' xviii.) are described as exhibiting different colours. This however, whether the passage be Homeric and genuine, or interpolated at a later though ancient period, may have been a specimen of *toreutic* art. That the ancient sculptors increased, or imagined they increased, the effect of their productions in marble by adding colour, not only tradition but existing monuments testify. It is therefore not only possible but highly probable that they had some process with which we are unacquainted, by which they were able to produce some similar effects in their metal works.

Sculpture, as it was practised by the most ancient nations, must be viewed in a very different light from that in which we consider its employment in more modern times. With a comparatively uncivilised and unlettered people sculpture and typical art were the only means of representing ideas, and it had its origin almost in the wants of man. With later nations (even of a remote antiquity) art became in a degree a refinement; and then the various changes and improvements were adopted that now occasion the difficulty in distinguishing between original and engrafted styles.

The few notices that are scattered over the writings of the ancients are quite inconclusive as to a common origin of art; although certain received opinions upon the subject are occasionally met with. The very late date of the oldest of these writers, compared with the undoubted antiquity of the arts of design, accounts sufficiently for the difficulties they laboured under in collecting any trustworthy evidence on such points, and for the fables, exaggerations, and contradictions that abound in their statements. The adventures and works attributed to Dædalus, for instance, are a proof of the limited knowledge that existed of the first artist whose name occurs in the annals of Greek sculpture. The inventions and improvements in various useful arts due to a series of artists, and for which a single life would be insufficient, are nevertheless all ascribed to this one individual, who, after all, bore a name that in all probability was merely a general appellation given in early times to any skilful workman or artificer. In the same manner we find the introduction into Italy of the plastic art (simple modelling) attributed by Pliny to a refugee from Corinth at so late a date as about 600 B.C. The arrival in Etruria of Demaratus may have introduced changes or improvements in the fabric and decoration of vases. The names of the artists who are said to have accompanied him, Eucheir and Eugrammus, sound like epithets indicative of skill, rather than simple names of persons. Some writers speak of images having fallen from heaven. These several instances are referred to in order to show that even where tradition had supplied scattered and undefined notices of works of art of a remote date, they had become so subject to change and misrepresentation as succeeding generations received and in their turn again recorded them, that it would be vain to place any dependence upon them for a history of the origin of art. The inquiry into the precise time, the country, the circumstances when the first efforts in sculpture were made, must therefore be attended with almost insuperable difficulties. Not so the establishment, at a later period, of epochs marked by changes in style, and what artists call treatment.

The desire to perpetuate the memory of extraordinary events, of remarkable persons, or of their actions; to honour heroes and benefactors even during their lives, and to hand down to future ages the fame of their exploits, has been universal, and has rendered the arts by which such an end could be attained objects of universal interest. The first works applied to this purpose were no doubt marked by the greatest simplicity. The oldest and most authentic histories speak of monuments erected to mark the scene of any remarkable incident; and although, at the early periods referred to, these monuments were only composed of rude blocks, or mere heaps of stones, still to such a simple commencement may doubtless, in a great measure, be traced the origin of sculpture. Jacob set up a heap of stones at Bethel† mark the spot where he had had his dream or vision. (Gen. xxviii. 18.) A similar simple memorial of a pillar and a heap of stones commemorated the covenant entered into between Jacob and Laban. (Gen. xxxi. 44.) A similar monument was built over the grave of Rachel. (Gen. xxxv 20.) Joshua also set up a great stone under an oak, "to be a witness." (Josh. xxiv. 27.) As late as the time of Pausanias, about A.D. 170, certain of the Grecian divinities were worshipped under the form of rude blocks or mere columns, or stones set upright (Paus. vii. 22); and even in the present day the custom exists in some countries of setting up a heap of stones to mark the spot where any extraordinary accident, such for example as a death from violence, has occurred. These are frequent in Italy, where the passer-by usually adds another stone to the heap, at the same time repeating a prayer for the repose of the soul of the deceased.

It has been said that the history of sculpture is almost the history of idolatry. Religious feeling doubtless had its share in forwarding the progress of the arts; for man, even in his rudest state, always has a belief that good and evil emanate from some superior power; and, unable to comprehend a divine essence or spirit, has by degrees been led to offer his addresses to some visible object as its representative. But it seems probable that the first images or statues were of men rather than of gods: and thus that human idols preceded those of divinities. This supposition is strengthened by the fact that the heavenly bodies were the earliest objects of worship among the heathen nations; and the symbols that were afterwards dedicated to them were most likely merely pillars of a conical or pyramidal form, and not imitations of the human figure; and when such works are referred to and called "graven images" by Moses, it has ingeniously been supposed to be in allusion to the signs or hieroglyphics inscribed or cut on them. The sun was worshipped at Emesa under the form of a black conical stone with marks to represent the sun. (Herodian, v. 6; Gibbon, vol. i., c. vi.)

Traditional accounts of wonderful feats in arms, the real or fabled history of a conqueror, or a lawgiver, or the founder of a nation, led in all probability to the first attempts at making a portrait figure or image, which a rude and uninformed people, always attracted by the marvellous, associating with it actions of supernatural prowess, would soon learn to contemplate with feelings both of admiration and of awe. Extraordinary respect would lead to the payment of extraordinary honours; and the elevation of heroes into divinities would be attended with little difficulty when time had obscured the real existence of the personages and weakened the remembrance of their actions. The imagination would easily be worked upon while the eye contemplated these first rude attempts at form; and thus men would be elevated into gods.

The oldest idols of Egypt, no less than the monstrous images of the Buddhists and Chinese, were probably, in the natural progress of superstition, the fruits of a similar origin. The general forms once admitted and consecrated, as symbolical of divine attributes, were afterwards, in some instances, preserved from innovations by the influence of the hierarchical institutions; and thus was a barrier raised which for a long period was fatal to the progress of imitative art. We are accustomed to look to the East as the nursery in which art and science had their origin; and it is probable that much in the Egyptian and even in the Grecian religious systems was derived from this source. In the representations of the deities of the Hindus, the human form is frequently combined with the brute,—the union of intelligence and force; and, as we know was the case with the Egyptians, the Hindu artists seem to have been subjected to some limitations and to a prescribed type. In all statues and rilievi that remain, many of which must have been executed at distant periods, there is the same prevailing character of form, expression, and attributes; while out of the immediate pale of their mythological or sacred system they appear to have been less restricted; and some of the sculptures at Ellora and Elephanta exhibit a feeling for composition, and a power of expressing character, which make it surprising that their sculpture never attained higher excellence.

In turning to the inspired writings, we find allusion made to imitative art in the earliest period of history. The Israelites, after the Exodus, are warned against the superstitions and corruptions that had by degrees crept in and deformed their primitive simple forms of worship, and are exhorted to return to a pure devotion, as for instance in the book of Joshua (xxiv. 2, 14, 15, 23).

Rachel, when she left her father's house with Jacob and Leah, carried away "the images;" and Laban pursued them in order to recover objects upon which he seems to have set a high value. This, we believe, is the earliest notice in the holy writings of the existence of such things, and even here we have no particulars by which any idea can be formed of what they were like, or of what materials they were made. That they were small is evident from the circumstance of Rachel being able to carry them away unobserved, as well as from the facility with which they were concealed when Laban "searched all the tent, and found them not."

No remains of Hebrew sculpture are known; but as early as the time of Moses they had attained to a considerable proficiency in some of the most difficult processes of art. The setting up of the molten calf, and the making of the brazen serpent, are evidence of this. The earliest recorded names of sculptors are in the Old Testament; Bezaleel the son of Uri, of the tribe of Judah, and Aholiab the son of Ahisamach, of the tribe of Dan. (Exod., xxvi.) They were the artists appointed to make the ornaments of the Tabernacle, and their date is therefore about fifteen hundred years before the Christian era.

From the peculiar position held by the Phœnicians, and their character for enterprise and ingenuity, it is much to be regretted that we possess no specimens of their design. The coins of Carthage, a colony of Phœnicia, are of too late a date and of too insignificant a character to throw any light upon the condition of sculpture among the parent people. The recent excavations and researches of Mr. Davis on the site of Carthage, have not brought to light any productions of a kind to elucidate what is doubtful with reference to the attainments of the Phœnicians in the higher branches of sculpture and of the arts generally. We can therefore only estimate their proficiency in all ingenious pursuits from the encomiums so generally passed upon them by ancient writers. While the neighbouring people were in a state of primitive simplicity or profound ignorance, the Phœnicians seem, by a native industry and disposition to exertion, to have made themselves celebrated for their arts and manufactures. Their country was the great mart and magazine of the known world. The prophet Ezekiel apostrophises Tyre as a "merchant of the people for many isles."—"The ships of Tarshish," he says, "did sing of thee in thy market; and thou wast replenished and made very glorious in the midst of the seas." Homer ('Iliad,' xxiii. 743) calls them "the *Sidonians*, the skilful workers or artificers" (Σιδόνες πολυδαίδαλοι), when he speaks of them as having made an elaborately worked silver cup. Solomon sent to Hiram, king of Tyre, for workmen to build and decorate his magnificent temple; and the king sent him a "cunning" man, skilful to work in gold, silver, brass, iron, stone, and timber. (2 Chron. ii. 13; and 1 Kings, vii.) The building of Solomon's temple took place about one thousand years before the Christian era.

With the exception of the Hindus, our remarks have thus far been confined to those nations among whom sculpture is known to have been practised, but of whose art no monuments remain. We are now about to enter upon a more interesting field of inquiry. Sculpture had in its first stage (when, as we believe, each people who employed it originated it for themselves) fulfilled its purpose as a sign or a record. Afterwards it acquired an increased dignity from being used to represent objects claiming admiration or respect; and it was in this stage probably that valuable materials were first used for sculpture. The progress was easy to employing it for decoration, and the Babylonians and Hebrews made great use of it for this purpose. But as yet no practical knowledge has been gained with respect to its progress as an art of design; of the changes from primitive rudeness to defined form and character; nor of the innovations or varieties in feeling or practice occasioned by the intercourse of hitherto strange and unknown nations.

The style of sculpture and the condition of the art at different periods among the Persians, the Egyptians, the Assyrians, the Etrurians, the Greeks, and the Romans, can fortunately be illustrated by reference to existing remains. Each of these people had their peculiar manner, which has given a character of *school* to their productions. In all of them the practice of art was more or less influenced by the priests, and by local and popular religious opinions; and it will be interesting to trace how far these influences affected the progress of sculpture, by restraining, as they did in some instances, its advancement towards perfection even as an imitative art; or in urging it forward, as among the Greeks, till it reached its highest excellence, by the union of subject, form, and expression, as a means of gratifying sense, exciting feeling, and elevating sentiment.

Sculpture was practised in Persia with very limited success. Various circumstances conspired to retard its progress. The Persians, disapproved of statues for religious purposes; that is, as objects to which worship should be offered. Not believing, as the Greeks did, that the gods had the human form, they admitted no representation of the deity, and allowed fire and water to be the only symbols or emblems of the divine power. It is said that Xerxes destroyed the temples of Greece at the instigation of the Magi, who exclaimed against the impiety of those who presumed to enclose within walls the gods to whom all things are open and free, and whose appropriate temple is the whole universe. Wherever they appeared as conquerors, the effects of this opinion were exhibited; and in Egypt, as well as in Greece, they gave full indulgence to the iconoclastic fury. It is not easy to determine the date of such sculptures as appear on Persian buildings. Those which decorate the structures at Persepolis represent religious processions chiefly, and sometimes combats both of men and beasts. In none of them is there any approach to a representation of the naked human figure. Their figures, enveloped in long heavy draperies, are deficient in grace, variety of action, and character. At a later period of their history some innovations seem to have been permitted, but these were not of sufficient importance to raise their art to any degree of excellence. The low measure of their attainments in this respect, and the general want of taste in art, are strikingly exhibited in the gold coins called *Darics*, which display as much poverty of design as meanness and clumsiness of execution. It has been thought that Persian art received some additions or modifications after the return of Cambyses from Egypt, when he probably was accompanied by some of the artists of that comparatively cultivated nation. There is however nothing in any of the monuments that remain which is evidence of this influence. In the treatment of the termination of the hair in small round shell-like knobs, and in the parallelism and uniformity of the long draperies, there is a strong resemblance between the styles of the Persian and early Greek and Etruscan monuments. If this is anything more than a general characteristic of primitive art, it only proves that the Persians were at one period not far inferior to their neighbours, but failed to make that progress in design and execution which eventually led to the perfection of art in Greece and Asia Minor.

In Egypt, on the other hand, distinct as is the quality of its art from that of Greece, sculpture was practised on a scale and for purposes that give it an irresistible claim to our interest. From all we read in ancient authors, and from all that modern research has brought to light, the Egyptians were learned, intelligent, industrious, and wealthy. Neighbouring nations considered Egypt as the centre and the source of all knowledge; and "the wisdom of the Egyptians" passed into a proverb. Of the power and the ingenuity of the Egyptians, even in the most archaic times, some idea may be formed from the magnitude and character of their remaining monuments of architecture and sculpture, some of which, of a finished style of art, are considered to be not only of a much earlier date than any known works of other countries, but older than any historical record that we possess. The date of the foundation of Thebes, the capital of Upper Egypt, and of Memphis, the capital of Lower Egypt, is undetermined; but it must be of a very high antiquity. At Karnak (a portion of Thebes lying on the Arabian side of the Nile) there are remains of sculpture which bear the name (Osirtasen) of a monarch supposed to have been contemporary with Joseph: and many of the ruins are attributed by archaeologists to a date long antecedent to that king. These monuments are mentioned merely in proof of the great antiquity of sculpture among the Egyptians, and as affording the opportunity of comparing the peculiarities of the style of art at that early time with that of works of later date.

Winckelman, Millin, and Fea have thought it possible to distinguish different periods, or epochs, in the history of Egyptian sculpture; but they have not agreed in their classification. This is not to be wondered at, when the general resemblance of style that pervades all Egyptian design is considered. In the course of ages, and especially under some of the more ambitious and enlightened of their kings, a grander style of form and greater variety of composition were indulged in. Still, the very slight variations that were made (for, considering the space of time over which the history of Egypt, as a flourishing nation, extends, they may truly be called slight) render any attempt at a satisfactory classification, or reduction of changes to chronological periods, almost hopeless. The only division of epochs of art in Egypt which is not open to dispute is, first, that of an original and preserved standard which, with slight variations and modifications, existed from the earliest date of art in the country down to the time of the arrival of the Macedonian Greeks in Egypt, that is, till about 330 B.C. The Greek dominion in Egypt constitutes the second period; and the style of art may perhaps not inappropriately be called Graeco-Egyptian, as it certainly was influenced by the taste introduced by that people. The next and last period may be termed the pseudo-Egyptian, or imitative period; and dates from the time of Hadrian, or about A.D. 130, when the Romans adopted many of the superstitions of the Egyptians, and added some of their divinities to their own extensive mythological calendar. This love of novelty, or subserviency to the caprices of their emperor, filled the cities and villas of Italy with statues of Isis, Osiris, and other personages and objects of Egyptian worship. No advantage, however, was gained by Egyptian art in consequence of the springing up of this fashion in Rome. The great endeavour was rather to give all design an Egyptian character, than to elevate the character of Egyptian art by the introduction of a superior taste either in form or composition. The most favourable specimen of the mixed style is the fine statue of the Egyptian Antinous, as it is called; but, founded on caprice and false principles, the Roman or pseudo-Egyptian manner soon fell into disuse, and has never been resumed. It will be remarked that in all the changes of circumstances to which we have referred, and by which the political condition of Egypt was materially affected, no sufficient alterations occurred to destroy the peculiar and distinctive character of Egyptian art, which exists in all its force, whether the works be of the most remote archaic period and of the whole range of time to Alexander the Great, of the time of the Ptolemies, or even the still more modern period of Hadrian.

It is indeed matter of surprise that a nation so celebrated as the Egyptians for superior intelligence, and of such long experience in the practice of the arts, should have made so little progress in them; and the phenomenon would be quite inexplicable if we were not acquainted with the nature of their institutions, and the check which was thus opposed to their advancement beyond a certain limit. The common speculations that have been offered with the view of accounting for the acknowledged inferiority of the Egyptians to the Greeks are altogether unsatisfactory, even if the facts upon which they are founded could be admitted. Some have supposed the absence of grace and the stiff uniformity of action in Egyptian design to be owing to the want of beauty in the natives of Egypt. Others have imagined that the artists' want of knowledge of anatomy, and there being no public games in which they could study the human figure, are sufficient to account for this inferiority; attributing to physical causes alone that which was effected by very different influences. The art of sculpture especially seems to have been employed exclusively for religious purposes. The priests, an hereditary body, systematically enforced the preservation of ancient usages, and confirmed their hold upon the respect, obedience, and veneration of the people by not suffering any innovation upon old established forms. The whole population was divided into castes, and a calling or profession was exercised from generation to generation. The sons were all obliged to follow the steps of the father. The order of these castes is variously stated by different writers. The sacerdotal, of course, ranked first. According to Synesius, the profession of an artist was not exercised by common or illiterate persons, lest they should attempt anything contrary to the laws and regulations regarding the figures of the gods; and Plato, in his second book of Laws, says, "they never suffered any painters or statuaries to innovate anything in their art, or to invent any new subjects or any new habits. Hence the art remains the same; the rules of it the same." Here, then, we see the real cause of the duration through a series of years of one unchanged style of art. The origin of the form preserved through so many ages is declared by its extreme simplicity. The earliest attempt at representing the human figure would be marked by the absence of action; and this is the characteristic of all Egyptian statues. The figure is upright, or kneeling, or sitting. The legs are close together, and the arms are attached to the body. This, then, became the established type; and though some slight movement was occasionally allowed, as in advancing one foot before the other, it hardly can be said to relieve the so improved figure from the stiffness of the more primitive standard. That there was a capability in the artists for mechanical excellence is amply proved by the more elegant forms that sometimes are met with even in Egyptian statues, but more especially in those works where they could without impropriety indulge their fancy. The heads of divine personages occasionally beam with majesty and grace; and in the examples in the British Museum of Egyptian monuments, whether in the head of the so-called Young Memnon, or in the Prudhoe Lions and other representations of animals, or in some of the compositions portraying scenes of active life, the student will perceive that some other cause than want of feeling or skill must have operated to prevent the sculptor of Egypt from arriving at the same eminence in art, that was attained by the artists of Greece. The stiff and limited action of Egyptian statues has already been noticed. To this must be added, that the figures of men are usually naked, excepting that a sort of apron is folded across the loins; while those of women are represented dressed in a long and simple garment fitted close to the body. This covering has no folds in it, and can only be distinguished from the figure by a slightly raised border at the neck and feet. The form of the breasts is sometimes indicated on the dress by their natural projection being circumscribed by an indented line. One of the most interesting specimens of Egyptian sculpture is now in this country. It is generally known as the head of the Young Memnon, though it has no claim to that title, which was given it from a mistake made by Norden, the traveller, who visited Egypt in 1737. This bust is formed of a single block of fine-grained granite, containing two strata of colour, one portion being of a red, the other of a gray (or blue) cast. Though it possesses all the characteristics which so eminently distinguish Egyptian sculpture,—the flat eyebrows, projecting eyeballs, the rounded nose, thick lips, and the ears placed high up,—this head claims admiration for beauty of outline and the peculiar sweetness of its expression. It offers a remarkable exception to the general rule of Egyptian design, and shows, what has before been hinted at, that there was the power of representing beauty both of form and sentiment, if room had been allowed for its exercise. In working basso-rilievo (and pictures) the Egyptian artists decidedly ventured beyond the limitations to which they seem to have been confined in representing insulated figures. Almost all the temples and tombs that have been explored are richly decorated with sculptures in the peculiar style of rilievo to which allusion has been made in the introductory part of this article; and although they do not materially differ in the general style and character of art, they are sufficiently varied in the mode of treatment to warrant this distinct notice of them. The most striking difference from the insulated figures consists in the superiority, as well as extent, of design and composition. This is particularly observable in the Theban remains, to which attention has been directed by Wilkinson, Rosellini, and others who have illustrated the history, arts, and customs of the ancient Egyptians. Wilkinson, speaking of Luxor and Karnak, observes as to the decorations of the temple, "The principal historical sculptures are on the exterior of the great hall. . . . . . The upper compartment represents the king attacking a fortified town situated on a rock, which is surrounded by a wood, and lies in the immediate vicinity of the mountains." In another compartment the king is again the hero, and is represented slaying the chief of the enemy with his sword, having first wounded him with his spear, and entangled him with his bowstring. The author observes here that the drawing of these figures is remarkably spirited. After other series or compartments, in which the Egyptian monarch is seen scattering death among his enemies, is a representation of his return, and the presentation, by him, of captives and spoils to the deities of Thebes.

All colossal works in Egypt are of basalt, porphyry, granite, or sandstone, though Herodotus (ii. 143) tells us that at Saïs and at Thebes there were statues, of large dimensions, of wood. We are not aware that any large statues have been found made of metal. The British Museum possesses three bronze figures which merit attention, as they exceed the usual dimensions of such Egyptian works, being about three feet high, and gilt. The substance or thickness of the metal is not great, and the interior is filled up with stucco or plaster. The gilding, some of which is well preserved, both in surface and colour, seems to have been applied as a wash, the bronze having first been entirely covered with a coat of plaster about as thick as a card.

The clean execution and exceedingly fine surface observable in the sculptures of Egypt have attracted the attention of practical judges, and led to the conviction that the Egyptians must have had great knowledge in the arts of hardening or tempering metal, to enable them to execute such highly-finished works in the most obstinate and brittle materials. It is a remarkable fact that when the colossal head before alluded to as the Young Memnon was placed in the British Museum, and it was necessary to cut some holes in it for the insertion of iron cramps to unite some of the broken fragments, the hardness of the granite was so great that six or eight blows rendered the mason's tools (which were tempered more highly than usual) totally useless.

The facilities that are now afforded the student and public for examining authentic monuments of Egyptian art in the extensive and valuable collection in the British Museum, render it unnecessary to dwell at greater length upon the peculiarities of that school of design. That their works are wanting in the grace, the flow of lines, and the beauty united with repose, that constitute the charm of the best Grecian sculpture, must at once be admitted; but the simplicity and clearness of intention in their more extensive compositions, and the sublime grandeur, repose, and dignity of their colossal statues, so appropriate to their mystic and religious purposes, will always ensure their being considered amongst the most interesting monuments of past ages.

Assyrian Sculpture.—Until so recently as 1843, nothing was known of the arts of the ancient Assyrians beyond the references to the splendid palaces filled with statues and painted bassi-rilievi on the walls, of vast size and admirable workmanship, in the Old Testament and in ancient Greek authors. But in that and following years a surprising number of the monuments themselves were brought to light by the fortunate researches of MM. Botta and Layard, and their successors, and transferred to the British Museum and the Louvre. The buildings in the buried ruins of which the Assyrian sculptures were found have been described, and the sculptures themselves noticed, under NINEVEH, ARCHITECTURE OF; here, therefore, it will only be necessary to indicate briefly their character. All the sculpture yet found, with the exception of a few bronzes, consists of slabs, often of colossal dimensions, on which are carved figures in relief, and with which the walls of the palaces were faced both inside and out. In date they are believed to range from the reign of Sardanapalus, B.C. 930, to the destruction of Nineveh, B.C. 625. As Nineveh was founded 1200 years earlier, they do not therefore represent the archaic period of Assyrian art. The existing examples appear to belong to three distinct periods. The earliest are those brought by Mr. Layard from the great palace and adjoining buildings in the north-west quarter of Nimroud, and now in the British Museum; they belong to the age of Sardanapalus, or about 930—902 B.C. They consist of colossal human-headed winged lions and bulls, personages from the Assyrian mythology, and other single figures; of representations of battles, sieges, the passage of rivers, the chase, the great king sacrificing, &c., cuneiform inscriptions being often carved quite across the slabs, without any regard to the figures. As works of art, they do not take a very high rank: the drawing of the human form is inaccurate, the muscles are exaggerated; there is utter ignorance of perspective; and the artists were evidently bound, like the Egyptian sculptors, to certain strict conventional rules. Yet it is impossible not to be struck in these older works with a certain largeness and severe grandeur of style and power of imitation. Here, as indeed throughout, Assyrian art seems to hold a sort of middle place between Egyptian and Grecian art. The slabs found at Khorsabad by M. Botta, and deposited in the Louvre, belong to a middle period, that of the 8th century B.C. Less severe and perhaps inferior in grandeur to the older works, they exhibit more refinement of execution. The Kouyunjik monuments in the British Museum are of the third period, or between B.C. 721 and 625. The slabs contain historical records, hunting scenes, &c., similar to those of earlier date, with some rather different in character, representing Sennacherib superintending the construction of some great architectural works, and directing the removal of colossal human-headed bulls. The scenes represented in the slabs of this third period are more varied in character, the execution is more careful, the figures are more minute and more accurate in the details,—in the animals, especially, the minute accuracy and knowledge of animal nature are quite remarkable,—but the largeness and grandeur of the older works are wanting. The slabs of each period are chiefly of alabaster, but some of the latest date are of the harder native limestone. All of them appear to have been painted with the most brilliant colours they were the figures pourtrayed with vermilion, exceeding in dyed attire, all of them princes to look at, described in the sacred scriptures.

Etruscan Sculpture.—The Etruscan is the next school of sculpture that claims attention. The history of this nation is involved in great obscurity. The appellations of Tuscan and Etruscan were foreign to them, and Etruria was a Roman term. The more ancient name by which they were called was *Rasenæ* ('Ρασηναι). Their later history is chiefly known from their connection with other nations. [ETRURIA, in GEOG. DIV.] An examination of their sculpture, as founded on the numerous existing monuments, almost seems to connect them, in a greater of less degree, with the Greeks. Whether the Etrurians at any time possessed a mythology and style of design on which Greek "myths" and forms were subsequently engrafted, or whether each nation retained principles originally common to both, is not important in this part of our inquiry. The supporters of the more remote antiquity and superior intelligence of the Etrurians have supposed it possible that this people, instead of being taught by them, were at one time the instructors of the Greeks, amongst whom, in consequence of their wars, internal divisions, and other disturbing causes, the arts were neglected, and probably suffered to fall to decay, while Etruria had enjoyed a state of comparative repose, favourable to the advancement of the arts. Among the great difficulties with which this part of the subject is embarrassed, is that of establishing with any certainty the dates of the settlement of Greeks in Etruria. It certainly is remarkable that the cinerary urns found in sepulchral chambers often have represented on them subjects whose meaning is unknown, and which seem to have no affinity at least with the *post-Homeric* Greek mythology; and so far the practice of art and a class of symbols seem to have existed in Etruria, either essentially its own, or, if ever shared with others, so ancient that all record of it was lost, excepting as it appears on these older Etruscan monuments.

The history of the known Etruscan school of sculpture is therefore necessarily founded on the character of the majority of existing specimens; and in these the recurrence of similar subjects and personages, resemblance of costume, and the common form of many of the letters of the Etruscan and Greek alphabets, distinctly establish the fact of some communication between the two nations. Lanzi ('Notizie sulla Scultura degli Antichi') divides the art of Etruria into epochs or periods, and considers the second to be that which was influenced by colonies from Greece; and it is this influence which is so observable in the monuments referred to.

In observing, however, that all or nearly all the specimens of Etrurian art that have reached our times indicate a connection or intercourse at some period between that country and the Greeks, it may be well to repeat a remark that has incidentally been made in a former part of this history,—to caution the student from too hastily attributing to different nations a common origin of design, from the mere similarity of certain forms and corresponding particulars of execution which may perchance be recognised or discovered in their primitive attempts at art. It must always be borne in mind that this appearance is often nothing more than the general characteristic of all art in its infancy; the same, or nearly so, in Greece, in India, in Etruria, as in all other countries. Lanzi observes, in speaking of the sculpture of this school ('Notizie sulla Scultura degli Antichi'), that a distinction must be made between works in the Etruscan style and works simply executed by Etrurian artists. The "Etruscan style" was a peculiar manner of treating art. It was designated by the Latins "Tuscanicus;" and all works executed in this manner were termed "opera" or "signa Tuscanica." That this distinctive character of school existed, and was recognised as a peculiar feature in art, is confirmed by a passage in Quintilian, in which that writer is particularizing the style of some of the great sculptors of Greece, and showing the changes or progress that distinguished the earlier from the later masters. He says, "Callon and Egesias made their statues hard" (a technical term meaning stiff and severe) "and nearly approximating to the Tuscan figures. Calamis made his works less rigid." (Quintil., 'Orat.,' lib. xii., 10.) The peculiar characteristics of the Etruscan style,—the *signa Tuscanica,*—are an affectation or exaggeration in the general actions and attitudes, and meagreness of treatment in the details. In the heads, whether of male or female figures, the hair is usually stringy; or plaited, and falling in long tails or lengths. The hands are placed in the least natural position for the purpose on which they are employed, and the ends of the fingers are often turned up in the most unnatural and therefore ungraceful manner. The draperies are cast without any regard to masses or agreeable forms, and always appear as if they had been put on wet and starched, and had stiffened in drying; the edges are very much shown, and in the falling or perpendicular views appear in regular and corresponding zig-zag lines. Many points of resemblance to the above works of the *signa Tuscanica* will be found in early Greek art, especially that of the Æginetan school. With these, however, this indication of primitive style passed away as the knowledge of art advanced, while the Etruscan manner was retained, and even imitated in many works of a much later period than the original Tuscan, and by artists belonging to schools of a more perfected taste. As a general remark, it may be observed that productions in the Etruscan style are very deficient in beauty. They neither exhibit the repose and simplicity which, notwithstanding its other deficiencies, give dignity to Egyptian, nor the fine forms and sentiment which ennoble Grecian sculpture; and whatever interest they excite is derived rather from the value that attaches to them in an archæological point of view, than from any merit that they possess as works of art.

It has been observed that some Etruscan works are found to differ from these in the style of their execution. This is particularly observable in the recumbent figures that have been discovered in the Volterran and other Etruscan tombs and hypogæa. Some of these are small, but many are of large size, and usually decorate the lid of the coffin or sarcophagus in which the ashes and sometimes the body of the deceased were deposited; closely resembling in this respect the style of monumental sculpture in Europe in the 15th and 16th centuries. In these figures there is a totally different character, both in form and expression, from the true Etruscan monuments. The heads frequently possess great beauty; there is often a strong character of nature in them, and it seems probable that they were intended to be portraits of those whose tombs they surmount. Many of them show marks of having been painted. The age of these works is undetermined. From the locality in which they have been found, and from the inscriptions which they bear, they would seem to belong to remote times of Etruscan dominion. In other respects, as in the general heaviness of the forms and clumsiness of drapery, they call to mind the style of art of a low Roman period; to which time, indeed, some antiquaries have at once assigned them. The question is not unattended with difficulty. There is every reason to believe that the ancient tombs of Etruria had been invaded, and in many instances opened and plundered, long before they were rediscovered by our modern archæologists and collectors. It is also probable that many of them have been used as depositories of the dead by a people much more modern than their original constructors. Objects have been found in them of various ages, from which it would appear either that many of the tombs and sarcophagi are really of a later date than usually has been supposed, or that the ancient burying-places have been used for the dead of a more modern race.

It is worthy of remark, as it may account in a great measure for the distinctive quality of Etruscan art, that Etruria, like Egypt, was ruled by a powerful hierarchy. Their chiefs, *Lucumones*, were priests as well as temporal rulers, and they may, like their Egyptian brethren, have exercised some influence in directing art, and in preserving from innovation the forms once consecrated by religion. It is at the same time probable that this influence was not so restrictive in Etruria as it was in Egypt; for the varieties that are found in works of art prove that the artists here took greater liberty than was permitted to those of Egypt. This appears to be the most reasonable way of accounting for the continuance of a distinctive style and limited progress of design among a people who were eminently clever (φιλοτεχναι) and ingenious. Considered in this point of view, Etruscan sculpture holds a position of great interest in the history of art. It is impossible not to recognise in it the connecting link between two systems, namely, the practice of art for hieratic or purely sacred purposes, and that more liberal and general development of it which, under the later and more refined Greeks, was directed to the illustration of the most poetical and sublime conceptions through the medium of the most beautiful forms. Of the great extent of their practice in sculpture a sufficient proof is afforded by the fact mentioned by historians that when after having sustained long and expensive wars against the Romans, the Etrurians were finally subdued by them, and became a Roman province (about 280 B.C.), two thousand statues were taken by the victors from Volsinii alone. (Plin., 'Hist. Nat.,' xxxiv. 7.)

The Etrurians were famed for their skill in making vases, and different towns became celebrated for peculiarities of manufacture. (Plin., 'Hist. Nat.,' xxxv. 45.) There is however reason for believing the greater number of painted *terra-cotta* vases, usually called Etruscan, from being first discovered in Etruria, to be Greek. Their subjects, their style of painting and design, evidently connect them with that people; and it has been observed, that though the Etrurians inscribed every other work of art with their own characters, there is scarcely an instance of a painted vase with any other than a Greek inscription: some of these may, however, be imitations of Greek vases. The Arezzo (Arretium) vases are of a fine clay of a red colour, but the figures are in relief: many of these are of a comparatively late period, and bear Latin inscriptions. (Inghirami.) The arrival in Etruria of Demaratus with artists from Corinth has been assigned as the date of the introduction of the art of making vases, and of other processes in the plastic art. It is, however, more probable that they only effected some changes in the style of design that already prevailed; for modern discoveries seem to establish the existence in Etruria of a manufacture of cinerary urns and vases long anterior to the appearance of the refugees from Corinth. (Lanzi, *l. c.*; Winckelman, 'Storia della Scultura;' Mrs. H. Gray, 'Tombs of Etruria.)

The Gallery of Antiquities at Florence contains several extremely curious specimens of Etruscan sculpture, especially in some figures of large size in bronze. Some of these have inscriptions on them. The bronze she-wolf, preserved in the Capitol at Rome, is also a remarkable example of ancient art in the Etruscan manner. The extensive discoveries that have been made in different parts of Tuscany of late years have likewise added greatly to our knowledge of the Etruscan art and customs, and have enriched the museums of Rome, Naples, Florence, and even England, with most interesting records of this remarkable people. The remains preserved in these and in private collections are well worthy of attention, but a detailed description of them belongs rather to the general history of the country and its antiquities.

The works in sculpture of the Etrurians are chiefly in *terra-cotta*, stone, and bronze; and the most ancient tombs have supplied some exquisitely worked ornaments in gold, as well as larger pieces of armour of the same costly material.

Greek Sculpture.—In the preceding pages we have had rather to notice its existence than to trace the progress of sculpture; for, with very limited exceptions, its practice was under circumstances so little favourable for its improvement, that it is scarcely possible to connect it, in any way, with the refined pursuit which it afterwards became in the hands of the Greeks. In other countries it never advanced beyond certain limits; mere representations of objects were produced seldom elevated by sentiment or feeling; and if, sometimes, the rudeness of first attempts at form was overcome, the art still remained in fetters. In Greece, on the other hand, sculpture soon rose superior to all those prejudices that would have restricted its advancement. With this gifted people it became something more than a merely mechanical pursuit. It was here that the conceptions of sublime and glowing fancies were embodied in the productions of what may truly be termed a race of poet-artists. Writers have endeavoured to account in various ways for this universally admitted superiority of the Greeks over every other nation among whom the fine arts had been practised, and usually have attributed their success to such physical causes as a fine climate, or the prevalence of beautiful forms, or to the public exercises so general in that country; or to the kind of government in those communities in which the arts were most successfully cultivated. Valuable as some of these conditions must be allowed to be towards the perfection of art, they are by no means sufficient to account for an excellence which, even amongst the Greeks, was both extremely partial with respect to locality and extent, and limited as to its duration. Nor were those particular states in which the arts of design most flourished peculiarly favoured beyond others in the causes supposed to contribute to that excellence. The climate of Attica, it is admitted, was unequal; and though vegetation appeared in the greatest luxuriance in some spots, in others the soil was barren and naked. With regard to beauty, too, there is no reason to believe that the people who most excelled in the fine arts (namely, the Athenians) were distinguished beyond all other Grecians for this quality. Cicero, indeed, makes a very remarkable observation which would go far to prove that the contrary was the fact. He says, speaking of the crowd of young men whom he saw at Athens, how few there were who were really handsome. ('De Nat. Deor.,' lib. ii., c. 79.) And it is curious also that of all the women whose celebrity for beauty has reached us, not one appears to support in this respect the honour of Athens. Phryne was a native of Thebes, Glycera of Thespiæ, Aspasia was born at Miletus, and when Zeuxis, the painter, desired to procure the most beautiful models for his Aphrodite, it is said he produced his masterpiece from the study of seven virgins of Crotona. It is not intended to deny the existence of beautiful forms amongst the Athenians, but simply to show that it is not to this exclusive possession that their success in the imitative arts can justly be attributed. The admiration of beauty amongst the Lacedæmonians is admitted (Ælian, 'Var. Hist.,' xiv. 27; and 'Athen.,' xii. 12); but the fine arts were not permitted to be practised in Sparta. In other parts of Greece also personal beauty conferred a title to distinction; the priests of the young Zeus at Ægium in Achæa, those of the Ismenian Apollo, and the boys who walked in procession at the festivals in honour of Hermes at Tanagra, were youths to whom a prize of beauty had been awarded (Paus., vii. 24; ix. 10. 22); but no school of art arose out of this which at any period equalled, or attempted to equal, that of Athens. It is scarcely necessary to allude to the question of government. The arts flourished where the most different forms existed. Corinth held a secondary rank among the cities of art, while Athens and Sicyon were in the first. Indeed, if wealth, pomp, and luxury had been necessary, or alone favourable, for the success of art, it would have been exhibited among the splendid communities of Asia, and not been left to its comparatively tardy development in the small, scattered, and often disturbed states of Greece. It was not to any of these accidents, either singly or collectively, that the perfection of Greek sculpture was owing. It was the principle upon which, among that people, imitative art was founded (and upon which it was practised throughout all its stages), that led to its excellence. The whole secret of the superiority of the best schools of Greece was in their making nature, in her most perfect forms, their model,—the only means by which perfection in art can be attained. As soon as they acted upon this knowledge, their sculpture became almost as divine as their great examplar.

Judging from their poetry, and from their art, whether in their sculpture or their painting, it would seem that the Greeks had an intuitive sympathy with beauty. The artists seem to have been careful never to lose sight of this principle, by expressing any passion or feeling under forms at variance with the simple laws of beauty. All extremes of expression are studiously avoided, and they appear to have chosen only those subjects for representation which allowed them to keep within these bounds. Pliny ('Hist. Nat.,' xxx. 37) mentions an artist who had an opprobrious nickname in consequence of painting low and common place subjects; and the Thebans had a law which subjected artists to a fine if their works were inferior in beauty to the objects which they professed to imitate. (Ælian, 'Var.,' iv. 4; Junius, 'De Pict. Vet.,' ii. 4; Lessing, 'Laocoon,' ii. p. 12.) This natural sensibility to the charm of beautiful forms was encouraged and assisted by the habits of the people. The gymnasia, or schools, in which young men were trained to take part in the public games, were frequented by all classes. Statesmen, philosophers, poets, and artists were in the habit of attending them, and were thus accustomed to see the human form in all its varieties, whether draped or naked, or in repose or in action; and while the sculptor was filling his mind with the beauty and capabilities of the human figure, the spectator was acquiring the knowledge that enabled him to become a competent judge of imitative art. The importance attached to distinction in these games rendered the education of the young men a subject of great care. Every means were resorted to in order to increase the elegance, the strength, the suppleness, and the active powers of the body; and the sculptor especially benefited by having constantly before him the finest forms that exact discipline and judicious training could produce. He was thus taught to seek the causes of the superiority of the victor in the race or the wrestling match; and by comparing or contrasting the different properties most generally found to exist in the conquerors in the various classes, to adopt those qualities in whatever characters he might be called upon to represent. The deep and spacious chest and broad shoulders of the brawny wrestler gave the type or distinguishing character of Heracles, and the class in which physical strength was to be exhibited: the clean legs, small well-knit joints, and light proportions of the victor in the foot-race, furnished the character of form of the messenger of the gods; while the union of strength and agility in the athlete, taught the sculptor how to make those combinations which eventually resulted in what is termed *ideal* beauty,—the statues of gods, demigods, and heroes. Having this access to the best models, and exercising his art under the eyes of critics who, from habit and observation, were as well acquainted as himself with his standard, it is not surprising that the sculptor of Greece acquired a facility and a power of representing every class of form unattained by any other people, and which have rendered the terms Greek and perfection, with reference to art, almost synonymous. The high purposes to which sculpture especially was applied, and the general interest that was felt in all works that were produced, account for the success with which the art was practised. The mind of the sculptor was enlarged while he reflected on the appropriation of his work and the great objects of his labours. His was not the ambition of present praise or profit. He felt, and truly felt, that his art, properly practised and rightly understood, was capable of producing great moral effects upon those who were to contemplate them; and consequently, in the best period of Greek art, the appeal was always made to the higher feelings rather than the mere senses. The artist did not produce his works to gratify a patron, but to improve a people; and whether they were destined to the temple, the grove, the portico, or the place in which the public games were celebrated; whether, like the Zeus of Olympus, they were intended to excite religious impressions of the majesty of the gods; or, as in the *icones* (or portrait statues) in Altis, to stimulate the energy of the youths of Greece to gain distinction in the public games—the sculptor felt, and he acquired power as he was impressed with the ennobling idea, that he was contributing to a great end. This is the principle of the success of the arts in Greece; and in the presence or absence of this recognition of the public utility of art, may be discovered the causes of its comparative success or failure in other nations and in later times.

In Greece, as in other countries, the earliest attempts at imitative art were extremely rude. Pausanias, who travelled in Greece about A.D. 170, mentions that at Pharæ in Achæa thirty quadrangular blocks of stone were worshipped, or at least honoured, as the symbols or representations of certain divinities. At Thespiæ Hera was thus recognised, and at Sicyon Artemis Patroa was represented by a column, and Zeus Milichius by a pyramid. (Paus., vii. 22; ii. 9.) The ancient statue, if it can be so called, of Aphrodite of Paphos, with others that might be referred to, were mere columns or stones set upright. The next step in art was in the attempt to characterise these shapeless symbols by giving them a human form. The upper part was shaped into the likeness of a head, and, by degrees, arms and legs were marked out; but in these early imitations of the human figure the arms were doubtless represented closely attached to the sides, and the legs, though to a certain extent defined, were still connected or united in a common pillar, as in the statues of the Egyptian school.

The history of Greek sculpture may be divided, generally, into four periods, each of which is illustrated by existing works bearing unequivocal marks of the progressive changes which attended the practice of the art from its rise to its decline. These greater divisions or periods might perhaps easily be subdivided into smaller parts; but, as the present object is to give only a general and comprehensive view of the history of Greek sculpture, it seems better to confine ourselves to a few great divisions. The student who desires a more extensive acquaintance with the subject will find ample information in the numerous valuable works that have appeared of late years, as well as in the opportunities that now exist of examining the remains of Greek art of all ages which are preserved in the museums of this and other countries. The four principal sections into which ancient Greek sculpture may be divided are—the Archaic, or most ancient period; the Phidian; the Praxitelian, which includes the period of Lysippus; and fourthly, the age of its decline.

The First period embraces all the uncertain age, of which little is known but what can be gleaned from the traditions preserved in ancient writers. It may be considered to extend to the commencement of that great change in the style of art which had its consummation in the school of which Phidias was the head. The Second division includes the period during which sculpture was practised in the grand or sublime style, and during which the scholars of Phidias executed their works on the principles which he taught and illustrated. The Third period is characterised by a more rich and flowing style of execution, as well as by the choice of softer and more delicate subjects than had usually been selected for representation. In this the beautiful was sought after, rather than the sublime. Praxiteles may be considered the first sculptor who introduced this more sensual, if it may be so called, style of art; and Lysippus contributed to advance it by the peculiar fulness, roundness, and harmonious general effect, by which it appears that his works were characterised. The Fourth and last period in this classification is that of the decline of sculpture; when, although the excellence of preceding schools was still admitted and often maintained, not only no advance was made, but artists were frequently led away by the love of novelty of design, or the desire to discover some new road to fame or profit, and neglected the means which ages of progressive improvement had shown to be the best and safest rules of practice. When this was the case, grandeur of style will be found to have given place to littleness, and the beauty and simplicity of general form and character were lost in individuality and minute detail.

The remains of Greek sculpture of the Archaic period are interesting to the antiquary, but they offer few attractions to the lover of the beautiful. Rigid and stiff in action, and rude and inelegant in form, the statues and rilievi of the infancy of Greek sculpture have very little to distinguish them, in these respects, from the earlier attempts of other nations. The first step towards a change was in the attempt to give action; and this was soon attended by fresh peculiarities of shape or figure in the parts. In this stage it will be observed that there is great energy or violence in the general design, with a lumpy or knotty character of form. The general proportions of the figures are thick in comparison with the length of parts. The breasts and shoulders are wide and broad, while the hips are narrow. The thighs and calves of the legs are large and heavy for the knees and ankles, and the feet are long and clumsily shaped. The treatment of the head is peculiar in the sculpture of this early period. The eye is usually long and narrow; and is slightly raised at the outer extremity. The mouth is open, and, owing to a slight curve or elevation at the extremities, has the expression of smiling. On the most ancient coins the hair is wiry, the lines being parallel and close together, in the apparent endeavour to give the effect of the whole by imitating every hair. This was more successfully attempted by executing the hair in masses; some very ancient works exhibit examples of this, where the effect is partially produced by small knobs or lumps. At a more advanced period the hair is executed in a more minute and careful manner, and with a more precise arrangement, combining as it were the particular character of the earliest treatment with the more general effect attmepted in the next stage of art. In this the hair is brought in nearly straight lines over the head, but it terminates in small round curls which are arranged with great regularity, and sometimes in two or three rows over the forehead, extending on each side to the temples and ears. Specimens of these modes of treatment occur in the early tetradrachms of Athens; in the heads of the figures in the statues found in the island of Ægina; and in the sculptures found at Selinunte in Sicily, as well as in other remains of small bronzes and early coins; and there are many examples of it preserved in the collection of antiquities in the British Museum. In male figures the beard, wherever it occurs, is wiry, and exhibits elaborate execution. There is a curious specimen of this in the head of a warrior in a group in the Selinuntine marbles above mentioned (and of which there are casts in the British Museum), as well as in the Æginetan marbles. The draperies in the sculpture of this early time are extremely thin, lying close to the figure (or to the ground, if in reliefs), excepting at the edges of the folds, which are sharp and angular; these are arranged with the greatest precision, opposite folds corresponding as nearly as possible with each other, with the edges shown, and terminating in a sort of regular zigzag series of lines. All these peculiarities are characteristic of the most ancient, or, as we have called it, Archaic art: and whenever imitations of it have been made in later times, these features of action, form, and treatment of drapery have been observed. Sometimes portions only of the peculiarities above pointed out will be remarked in genuine ancient works, but of a later age than that under consideration. The sculptures alluded to as Æginetan offer examples of this; the treatment of the heads being characteristic of an earlier age of the art than the rest of the figures. This is doubtless to be attributed to a feeling of veneration for the older forms and received traditions of certain personages, such as divinities and heroes; and in this respect obedience to prescription marks the Greek as it did the Egyptian and other schools: with the former however it lasted for a limited period only; with the latter it extended throughout their whole existence.

The first sculptors whose names are recorded are Dædalus, Smilis, and Endoeus. The earliest person called Dædalus was descended, according to the ancient traditions, from a royal stock, being grandson of Erectheus, king of Athens. He is said to be the first sculptor who ventured to separate the legs of his statues. He also was the inventor of the saw, the axe, lever, &c. It is impossible to say how much fable and exaggeration have been admitted into the accounts of this remarkable discoverer; and it is equally vain to attempt to distinguish the inventions of the earlier artificers who bore this name, from the improvements introduced at subsequent times by others so called. Dædalus was in all probability a general title, for some time, given to any distinguished mechanist or figure-maker, as figures of a certain style or character were denominated Dædala (Δαίδαλα). Pausanias (ix. 3, &c.) says "the ancients called wooden figures Dædala;" and he adds, that he thinks it likely that the artist was called after the works, rather than by his own name; thus making Dædalus a title or surname. The same author was shown some wooden statues attributed to Dædalus, which he admits were not beautiful, but he says there was in them a certain air of grandeur (ii. 4). Smilis was a native of Ægina, and the son of Euclides. He was said to be contemporary with Dædalus, and he made a statue of Juno at Samos. Endoeus was an Athenian, and a scholar of Dædalus, and, according to ancient writers, executed various important works. Pausanias (vii. 5) speaks of a colossal statue in wood of Minerva Polias, which was preserved in his time in the temple of Erythræ in Ionia. It was a seated figure. Other statues by this artist are also mentioned, executed in stone and in ivory.

A mere list of the earlier Greek sculptors can throw little light upon the state of the art; more especially when the existence of many of those whose names are handed down to modern times may fairly be questioned, at least as to the dates assigned to them; and of their skill we certainly possess no authentic examples.

About 869 B.C., Phidon of Argos is said to have struck the first money in Greece, in the island of Ægina. Some extremely rude and simple coins of that island are extant; the device is a tortoise; and from the very primitive style of execution, they are thought not to be very remote from the period alluded to. It has been supposed that the employment of metal for sculpture took place soon after the striking of money under Phidon; and about this time we find mention made of statues of brass or bronze.

Among the sculptors recorded in the annals of art is Gitiadas of Sparta, of whom there were works remaining at Lacedæmon at the time of Pausanias (lib. iii. 17). Gitiadas exercised the profession of architecture as well as sculpture. Learchus also, a sculptor of Rhegium, is placed about this date. Pausanias mentions a bronze statue of Zeus at Lacedæmon, which was said to be by Learchus, and he calls it the most ancient statue in that material known to exist. The next names of importance that occur in the history of art are Telecles, Rhœcus, and Theodorus, to whom sculpture seems to have been indebted for various and great improvements. Their reputation for skill was so high, and their innovations in the practice of art so important, that they were even called inventors of some branches of it, which, however, it is obvious must have been known long before they appeared. Such, for instance, was the case with modelling, or the plastic art, which Pliny ('Hist. Nat.', xxxv. c. 12), recording without examination all that he read, says was attributed to them; though he himself declares that this discovery was claimed by or given to Dibutades of Corinth. Rhœcus and Theodorus were born at Samos. ('Paus.', viii. 14.) There appear to have been two sculptors of the latter name; one the son of Rhœcus, the other of Telecles. Rhœcus, architect as well as statuary, is said by Herodotus (iii. 60) to have built the temple of Hera at Samos. He was also considered the author of a statue, of a female, which the Ephesians called Night. Pausanias says that he was unable to find any bronze work of Theodorus; but Pliny alludes to several by an artist of that name. Theodorus, the son of Telecles, was considered the inventor of an art which was rarely exercised by the ancients, that of casting figures in iron. According to Herodotus, Theodorus engraved the celebrated ring of Polycrates, tyrant of Samos. He is also said to have made one of two magnificent vases which were presented by Crœsus, king of Lydia, to the temple at Delphi. It has been argued from this circumstance that Theodorus must have lived at a later date than that usually assigned to him. But it is not stated that the vase was made expressly for Crœsus. It is more probable that it was among the treasures of the king, and from its age, the reputation of its maker, and its intrinsic value, might have been thought worthy of dedication. Theodorus is noticed by Pliny for a work of great delicacy and minuteness, a statue in brass of himself, holding in one hand a file, alluding probably to his profession; in the other a *quadriga*, so small that a fly might cover it with his wings. With respect to the dates of the above artists, Pliny says they lived long prior to the expulsion of the Bacchiadæ from Corinth, an event which occurred in the thirteenth Olympiad, about 659 B.C. It is conjectured, therefore, that Rhœcus, and the first and second Theodorus, lived between 800 and 700 years B.C.

The introduction of casting in metal forms an interesting epoch in the history of art, and it is to be regretted that our information with respect both to time and place, that is, the part of the country in which it was first practised by artists of Greece and Asia Minor, is so limited. The fact of Learchus of Rhegium being recorded as one of the earliest statuaries would lead to the inference that the art was known in Italy before it was adopted in Greece.

Some antiquaries place Dipœnus and Scyllis between 800 and 700 B.C., a date which Flaxman ('Lect.', p. 75. 79) adopts in speaking of these sculptors. Others supposed they lived as late as 540 B.C. They have been called the first artists who employed marble for sculpture (Plin., 'Hist. Nat.', xxxvi. 4), but it is more likely that the expression upon which this opinion has been founded means that they were eminently distinguished for their skill (which may have been extraordinary at the time) in working in that beautiful material. They were employed by the Sicyonians to make for them certain statues of their gods; but we are told that having taken some offence, they quitted Sicyon, leaving their work unfinished. The country was soon after afflicted with famine; and, upon consulting the oracle, the Sicyonians were told that it would cease when the statues of the gods were completed. Dipœnus and Scyllis were persuaded to return, and they finished the statues; they were of Apollo, Artemis, Heracles, and Athene. Among their numerous scholars we find Learchus of Rhegium, which will account for the earlier date that is assigned them. They are also called the masters of Tectæus and Angelion, Dorycidas, Dontas, Medon, and Theocles. ('Paus.', ii. 32; iii. 17, &c.) Dipœnus and Scyllis were considered the founders of the school of Corinth.

From the earlier time of which mention has been made, down to about 550 B.C., there probably was little change in the style of sculpture, although great improvement in execution or mechanical power doubtless extended the extensive practice which the growing admiration of art occasioned. In a country in which all the efforts of genius were justly appreciated, sculptors, who were called upon to represent the most exalted objects, were likely to exert themselves to the utmost to arrive at perfection; and the remains of art afford sufficient evidence that from the time alluded to, that is, between the 6th and 7th centuries before our era, when the first difficulties had been surmounted, the advancement of sculpture was rapid and uninterrupted.

It is not necessary to give a mere list of names of the artists who are supposed to have lived to this time. So much that is uncertain is mixed up with the notices of them that are found in Pliny, Pausanias, and others who refer to them, that the inquiry into their personal history would rather impede than advance our present object.

Up to the period at which we are now arrived, sculpture seems to have been practised most generally and successfully in the Greek colonies of Asia; but the consequences of the revolt against Darius, the son of Hystaspes, were utterly destructive to their further progress. Many of the temples were burnt by the Persians, and the inhabitants were carried to distant places, or were reduced to a state of slavery. But as art fell in Asia, it acquired vigour in Europe, and the artists of Ægina, Sicyon, and Corinth diffused the principles of good taste and the knowledge of art throughout neighbouring countries; a feeling for a grand style of sculpture was soon exhibited wherever any opportunity occurred for the practice of the art. It is interesting to be able to refer, in illustration of the character of the art at this time, to some undoubted remains of sculpture of a period certainly not very remote from that under consideration. These consist of eleven statues which decorated the western and five statues that stood in the eastern pediments of a temple in the island of Ægina, where they were discovered, in the year 1812, by some English and German travellers. An account of them, with a detailed notice of their style of execution, is given under ÆGINETAN ART.

The Selinuntine marbles, so called from their having been found at Selinunte, on the site of the ancient Selinus, in Sicily, are very curious examples of early art. They consist of fragments of marble alti-rilievi, and seem to have formed part of the decoration of two temples, of which traces still remain. There are some peculiarities about these sculptures which are characteristic of two different styles of art. Those which belonged to one (distinguished as the Eastern) temple, have many points of close resemblance to the style of the Archaic (Æginetan) school, while those of the western temple appear to have come either from a more barbarous hand, or to be of a much earlier date than the others. Without having the sculpture to refer to, it is difficult to explain in what these peculiarities consist, but a comparison of what remains of a head of Athene, and that of a dying or wounded warrior, with some others of the collection, will suggest the inference we have ventured to draw. The head of the dying figure closely resembles (in character) that of the warriors in the marbles of Ægina; in the other figures there is a greater resemblance to the full overcharged forms described as characteristic of the very earliest art, and approaching indeed in some degree to the works of the Egyptians. At a later period than that to which these sculptures may be referred, the artists of Ægina were invited by the tyrants of Sicily to execute works in that country. It is highly probable, therefore, that in more remote times, and when art was still less known or practised there, foreign artists should have been employed in furnishing the decoration of the temples of newly founded cities. These artists would be the most esteemed of the time, and the rising school of Ægina would doubtless take a high rank amongst them. Joined with these, or probably working under them, the natives of the country might also have contributed their ruder efforts towards the same important object, and this would sufficiently account for the difference referred to with respect to the style and treatment of the various works.

From about 500 B.C. the succession of the great sculptors of Greece, and the changes that each master and his school effected in the style of art, can be traced with tolerable accuracy. Sicyon and Ægina were the most celebrated schools of sculpture, and unrivalled for the high quality of their bronzes. After Callo, or Callon, a sculptor whose date is very uncertain, the Æginetan artists of the greatest celebrity seem to be Glaucias and Onatas. These artists were much employed by Gelon, the tyrant of Syracuse, and his successors. Onatas, the scholar of Tectæus and Angelion, enjoyed a high reputation, and, judging from the numerous works which Pausanias (lib. vi., viii. ix., x.) attributes to him, must have had very extensive employment. This writer speaks of a colossal statue in bronze of Apollo, which was at Pergamus, the work of this sculptor; likewise a statue of Ceres, which he made for the Phigalians. There were also several works of Onatas at Olympia. One was a colossal bronze figure of Heracles, placed there by the Thasians. For the people of Pheneos he executed a statue of Hermes, dedicated also at Olympia. In this work he had the assistance of Calliteles, who was his scholar, and probably his son. (Paus., v. 27.) Onatas and Calamis worked together on a chariot and accompaniments, which was dedicated at Olympia, after the death of Hiero, king of Syracuse; and in another great work described by Pausanias, we find Onatas associated with Calynthus, showing that it was not unusual, nor considered derogatory to either, to secure the talents of various artists in one work. According to the above-mentioned writer, Onatas was a painter as well as statuary. His performances spoken of in this branch of art were executed for the Platæans: one of his pictures, with a work by Polygnotus, was preserved in the temple of Athene Area. (Paus., ix. 4, 5.) Sculpture was now rapidly approaching towards the perfection which it attained under Polycletus and Phidias; and an event occurred in the 5th century before the Christian era, which tended to accelerate this progress. This was the disastrous termination of the expedition of Xerxes against Greece. The failure of this vast undertaking showed the Greeks their own strength, while it also exhibited to them the immense wealth of the invaders, and placed in their hands the means of effecting the most costly improvements and decoration. It was customary in Greece to dedicate a tenth of all spoils gained in battle to the service of the gods; and that proportion of what was obtained from the Persians was, as a matter of course, appropriated to that purpose. Its value was expended on the construction of magnificent temples, enriched with sculpture and painting, and ornamented with vases, tripods, shields suspended as trophies, and every variety of decoration. The Persians, in their invading march, had destroyed every temple that they met with; but after their retreat and disgrace, they were all restored with increased magnificence. The ample employment thus afforded for their talents, and the high purposes to which their works were destined, excited a noble spirit of emulation among the artists, whose minds seemed to expand with the greatness of the objects required of them.

The gradual improvement of style in art, from the Archaic period, and through the early Æginetan and Athenian schools, is traced by some of the ancient writers. "The works of Callon," Quinctilian says ('Orat. Instit.,' xii. 10), "with those of Hegesias, are hard, and approached what was distinguished as the Etruscan manner. Calamis was less rigid, and the style of Myron, who followed, was still more softened." In Cicero we find a still more extended list, and a confirmation of the quality of improvement down to a contemporary, as in the above instance, of Phidias, the great master of sculpture. He says that statues of Canachus were more rigid and hard than was agreeable to the truth of nature. Those of Calamis were also hard, but still they were of a softer character than those of Canachus; nor were the works of Myron close enough to nature, though there could be no doubt that they were very beautiful; but the productions of Polycletus, he adds, were still more beautiful, and were truly perfect. (Cic., 'De Clar. Orat.,' c. 18.)

The history of the progress of sculpture in Greece has now been carried through the earlier schools, into a period at which it may be considered to have reached its perfection, as far, at least, as regards the principles on which it was practised. The chief sculptors of this age were Hegias, Pythagoras, Ageladas, Myron, Polycletus, Phidias, Alcamenes, and others. Hegias, Egesias, or Hegesias, has been noticed among the sculptors of an improving class, but whose works still gave indication of belonging to the Archaic time.

Pliny distinguishes at least three statuaries of the name of Pythagoras, but although allusion is made in ancient writers to artists so called of Samos, Rhegium, and Paros, it appears probable that there were only two of very high reputation. The most celebrated was a native of Rhegium, and the scholar of, or, more correctly speaking, of the school of Clearchus. (Paus., vi. 4.) He executed, among other works, several statues of conquerors in the public games, and he eminently contributed to advance the character of sculpture by his success in giving expression to his statues. Till his time this quality, so indispensable to excellence in art, seems to have been little thought of. A work by him is particularly alluded to for its excellence in this respect: it was a figure of a lame or limping man, in which the expression of anguish was so admirably pourtrayed, that the spectators were affected, and seemed to feel the pain he was suffering. Pythagoras is also noticed as being the first who represented veins in his statues, and as having bestowed greater care upon the treatment of the hair. From these curious and interesting particulars it is easy to see in what manner the dryness and almost prescriptive character of early art was giving way to the bolder as well as more refined treatment of the Phidian age. Pythagoras may be placed about 480 B.C. He had a scholar called Sostratus. (Pliny, 'Hist. Nat.,' xxxiv. 8; Paus., vi., &c.)

Ageladas holds a distinguished rank among the sculptors of antiquity, not only from the quality and number of his works, but also from the circumstance of his having been the master of the three most eminent artists of the brightest period of sculpture, namely, Myron, Polycletus, and Phidias. He was a native of Argos. There is some reason to think that there were two sculptors of this name. Pausanias (iv., vi., vii., and x.) alludes to various statues by Ageladas. He seems chiefly to have worked in bronze.

Myron was a native of Eleutheræ, according to Pliny ('Hist. Nat.,' xxxiv. 8), or an Athenian, according to Pausanias (vi. 2, &c.). There is no artist of antiquity who is mentioned more frequently or more honourably than Myron, and it is scarcely possible to believe that such universal praise would have been accorded if his works had not fully deserved it. It is unfortunate that no known production from the hand of this distinguished artist has reached our times. The only work of which any judgment can be formed is his famous statue of a Discobolus. Various copies of this figure are believed to exist. The best is in the Palazzo Massimi in Rome. The Discobolus, in marble, in the collection of sculpture in the British Museum (see the article Discus), is also believed to be a copy from the same celebrated original. A mere list of the works of this sculptor is unnecessary in this place. The chief of them are noticed under Myron, in the Biog. Div. The peculiar characteristic of the sculpture of Myron seems to have been expression. Petronius, in spite of Pliny's assertion, leads us to believe that this was the great excellence of Myron; he says, "Myron qui pene hominum animos ferarumque ære expresserat." With respect to his style, it seems probable, from some remarks of Pliny, that his works still exhibited certain peculiarities of treatment that belonged to a ruder age, though he gives him the high praise of superiority, in some respects to Polycletus. He says he introduced more variety into his figures, for this seems to be the true interpretation of the expression of the above writer. "Primus Myron multiplicâsse varietatem videtur, numerosior in arte quàm Polycletus," &c. ('Hist. Nat.,' xxxiv. 8.) The works of Myron were chiefly executed in bronze. He used that which was made at Delos, while his rival Polycletus preferred that of Ægina. Though chiefly celebrated for his productions in this material, he worked also in marble, and a statue is mentioned by him of Hecate, made of wood. (Paus., ii. 30.) Myron had a son called Lycius, also a distinguished sculptor.

Polycletus of Sicyon was one of those who eminently contributed to ennoble art, and to carry sculpture to perfection in what has been called the sublime style. In one respect he is said to have been superior to Phidias himself; inasmuch as he was considered to have carried to perfection the *Toreutic art*, which Phidias had only, as it were, commenced. Polycletus was the author of that perfect rule of proportion called, by way of distinction, the *Canon of art*. [Polycletus, in Biog. Div.]

The name of Phidias completes, or rather crowns, this list of the great originators of the highest style of sculpture. [Phidias, in Biog. Div.] The most splendid and the most perfect productions in the art were executed by him, and as long as the principles which he taught were retained, sculpture seems truly to have merited the epithet of sublime. Phidias was called the sculptor of gods; and the majesty of his Olympian Zeus was declared, in the forcible language of an ancient writer, to have added something to the beauty or sublimity of religion. That works of art are capable of exalting the mind, and rendering it susceptible of the most pure and elevated feelings, there can be no question, and this doubtless was the effect produced by the awful grandeur of this far-famed statue. Panegyric has almost been exhausted in recording the merits of this sculptor; but there is no reason to doubt the justness of the honour paid him. Many of his finest productions were in existence when, even comparatively late writers were living, so that the accounts that have come down to us are not merely the repetitions of unsupported or unproved traditionary encomium. The statue of the Olympian Zeus was existing till the year 475 of our era. It was then destroyed by fire at Constantinople; whither it had been transported by the emperor Theodosius the First. Unfortunately no remains of the greater works of Phidias have reached our times; but we have abundant opportunity of judging of his excellence, from the sculptures which, under the title of the Elgin Marbles, form a part of our national collection of antiquities. There is no doubt that these are the productions of this great artist; many of them probably from his own hand, and all executed under his immediate direction. They formed part of the decoration of the Parthenon at Athens, of the building and enrichment of which Phidias had the entire direction. The architects Callicrates and Ictinus worked under him. These sculptures consist of the statues and groups which were placed in the pediments of the temple; of several metopes, in alto-rilievo; and of a considerable portion of the frieze of the cella, in basso-rilievo. [ELGIN MARBLES; ALTO-RILIEVO.]

The perfect acquaintance which the best sculptors of this time had with the anatomy and character of animals is worthy of remark. The skill of Myron has already been alluded to. The horses in the Elgin Marbles are admitted by competent judges to be representations of the finest shape and of the best blood. The commonest observer is struck with their spirited and at the same time graceful action. In short these works may be studied with advantage for every quality that sculpture should possess; for truth, beauty, expression, and composition, united with the purest style and most masterly execution; and they may justly be considered the finest specimens of ancient sculpture that are known to exist.

It may be as well to offer in this stage of the history of the art some observations upon the combination or mixture of materials in sculpture. The custom of using a variety of materials for the different parts of statues, as marble, or stone, or wood for the heads, hands, and feet, and metal for the draperies and accessories, was very general throughout Greece and Asia Minor from a very early period; and although it militates against the received notions of a pure taste, the practice was in full force during what has always been considered the best period of art, namely, the age of Pericles and Phidias. Nor was this mixture of materials the only interference with the simplicity which some have supposed a principle and essential quality of Greek art. The hair of marble statues appears in some instances to have been gilt, and even colour was added to heighten effect. The background of works in rilievo was frequently painted blue, remains of which may still be traced on many ancient works. (Kugler, 'Polychromie,' &c.; Millingen; Müller.)

The occasional practice of introducing eyes of silver, glass, or paste, has already been alluded to in the introductory part of this essay, in speaking incidentally of Polychromic and Polylithic sculpture. The injurious effect of this introduction of gaudy and sparkling foreign substances upon the higher qualities of any work, such as its composition and expression, seems to be beyond dispute. It may be judged of in wax figures, and in some of the richly dressed and elaborately worked and ornamental images in Roman Catholic churches, and in Hindu temples. No arguments, even when supported by the authority of ancient practice, can render such works otherwise than disagreeable as imitative art to any but vulgar minds. An artist of superior power might possibly so treat his work that its expression, the beauty and grandness of its forms, and the scale on which it is executed, might take such entire possession of the spectator as to make him overlook the incongruous mixture of materials; but it is inconceivable that, with their refined taste, extreme sensibility to beauty, and great knowledge of the essentials of art, the Greeks could ever have preferred works of this kind to those of more simple composition. The probability seems to be that the employment of ivory and gold was owing as much as anything to the desire to use the most costly materials, as all the important works so composed appear to have been executed under peculiar circumstances, either as great national contributions, votive offerings in honour of the gods, or as trophies. In the case of tenths of spoils, when vast riches had fallen into the hands of the Greeks, and were devoted to a particular purpose, it was essential to find employment for them in exclusive furtherance of that object; and as the architectural details of their temples were richly ornamented and painted, and even golden shields were suspended over the architraves and friezes, it was natural to expend a liberal portion of enrichment on the statue of the presiding divinity. This opinion receives some support from the fact that the practice seems to have been almost if not entirely discontinued as the taste for art for general purposes increased. When we read of exquisite productions by Praxiteles, in marble, or Lysippus in bronze, there is no mention of works executed at the same period in richer materials.

Sculpture in gold and ivory has been called *Chryselephantine*, from the Greek words χρυσὸς, "gold," and ἐλέφας, "ivory." It was not first introduced at the time to which our history has reached, as Pausanias describes works so composed, of a much earlier date, existing in the Heræum, or temple of Hera, at Olympia, as well as in other places; but it was during this period that it was carried to its highest point of excellence. The two most celebrated works recorded in these costly materials are the masterpieces of Phidias. They were, the statues of the Athene of the Parthenon, and that of the Olympian Zeus in his temple at Elis. The exposed parts of the figures were made of ivory, and the drapery and accessorial enrichments of gold. Of the enormous value of this kind of work some idea may be formed from the accounts of the ancients, that the figure of Athene was twenty-six cubits high, and that the gold employed on it weighed forty talents. (Plin., 'Hist. Nat..' xxxvi. 5; Thucydides, ii. 13.) One writer says there were fifty talents of gold on it. (Diod. Sic., xii. 40.)

Chryselephantine sculpture seems to have been a branch of what the ancients called *Toreutic*. The exact meaning of this term has not been satisfactorily explained. (See 'Le Jupiter Olympien,' par Quatremère de Quincy, where several opinions are collected; also 'Archäologie der Kunst,' by Müller; Millingen, 'Ancient Inedited Monuments,' &c.) It was probably used to describe sculpture in which metal, which was worked or chased, was combined with other materials. Pliny says Polycletus brought the art to perfection. ('Hist. Nat.', xxxiv. 8.)

The ancient writers do not furnish any particulars as to the mode of executing these colossal works in materials which sometimes, as in the case of ivory, could only have been supplied in comparatively small pieces. Pausanias (v. 15) tells us that an edifice called the workshop of Phidias, near to Altis, was pointed out to him. It was there, he says, that the sculptor worked each of the parts of the Olympian Zeus. In addition to the original cost of these productions, there seems to have been great care necessary to preserve them. The Olympian Zeus was surrounded by a groove or channel of black marble containing oil. The object of this was, first to supply the necessary quantity of moisture to preserve the ivory; and secondly, to secure the work from damp, as the Altis was situated on marshy ground. Means were also adopted at Athens for preventing injury to the ivory parts of the Athene, from the too dry situation of the Acropolis. We are told that the statue of the Olympian Zeus was out of repair very soon after its completion; and the fact of the Phædruntæ being established to take care of the work, is a proof of its liability to accident. Pausanias mentions a remarkable circumstance connected with the persons appointed to this duty. It had been entrusted to the descendants of Phidias, and he says that it was in the same family in his time.

The scholars and followers of Phidias were Agoracritus of Paros, Alcamenes of Athens, Colotes or Colotas, Pæonius, and others. The first two deserve notice for the celebrity of their names and works. Agoracritus was the favourite scholar; Alcamenes, judging from the accounts left of him, the most able artist. He was considered second only to his great master; and one author, alluding to the progress made in sculpture, even classes him with Phidias, saying, that what was wanting in Polycletus was to be found in the works of Phidias and Alcamenes. (Quinctilian, lib. xii., 10.)

The sculptures of Phigalia, consisting of a series of alti-rilievi, representing the battle of the Lapithæ and Centaurs, and of the Greeks and Amazons, are of this age. The temple of which they formed part of the interior decoration was built by Ictinus, the architect, under Phidias, of the Parthenon; and from the style which pervades them, there is every reason to think these compositions proceeded from the same source as the sculptured portions of that edifice. The inferiority of their execution may be easily accounted for by supposing the working out of the designs of the master to have been left to the scholars or inferior artists. These interesting remains have already been more particularly described. [PHIGALIAN MARBLES.] The original sculptures are preserved in the British Museum.

The influence of Phidias continued to be felt for some time. Art had gradually been relieved from the dryness and hardness of the Æginetan school, and Phidias produced out of it the grand character which marks his period; but it appears there was still remaining a severity both in the forms and in the treatment, in the works of some of the artists of this school, which it was left for a sculptor of a succeeding age to remove. This change, which stamped the character of a new school of sculpture, was effected by Praxiteles.

When the restrictions which originally confined sculpture to religious purposes and prescribed forms had once been disregarded, and the art was applied to represent objects of general beauty and interest, it rapidly underwent changes; and the sculptors of the period which we are now considering, that is, at about 350 B.C., succeeded in introducing an entirely new quality of art. The grand, the sublime, and the severe, gave way to the soft, the flowing, and the graceful. At the head of these innovators was Praxiteles. He worked in bronze and in marble; but his most beautiful and admired performances were probably in the latter material, in the working of which he exhibited the greatest skill, and in which he is said to have introduced processes unknown to his predecessors. [PRAXITELES, in BIOG. DIV.] He is supposed to be the first sculptor who ventured to make a statue of Aphrodite entirely naked: all statues of female divinities were anciently draped. (Millingen, 'Monuments,' x. p. 7.) Such an innovation was considered extremely indecorous; but it was excused in this instance, on account of the beauty of the performance. Subsequent artists, desiring to reconcile a mode of representation so favourable to the purposes of art, with the prejudices still existing in a degree in matters pertaining to religious personages, seem to have adopted a middle course, as is seen in the two statues of Venus called of Capua and of Melos. ('Museo Borbonico;' 'Galérie du Louvre.') In these the forms are left entirely naked down to the middle, from whence rich drapery falls to the ground, covering all the lower portion of the figures.

The next name of importance, as the leader of a new school, is that of Lysippus of Sicyon. The reputation of this artist is not inferior to that of any sculptor who preceded him. He appears to have worked exclusively in bronze; and, according to Pliny, executed as many as six hundred and ten works. [LYSIPPUS, in BIOG. DIV.] A colossal statue at Tarentum by him is much distinguished. Lysippus was the favourite sculptor of Alexander the Great, and had the exclusive privilege of making statues of him. A long list of works by Lysippus is furnished by Pliny, Pausanias, and other writers. He is said to have paid great attention to the treatment of hair, and to have introduced an improvement in proportion, making the heads of his figures smaller than his predecessors had done. He doubtless observed that his figures gained in elegance and effect by taking this liberty; for a saying of his is recorded, "They (the older sculptors) made men as they were; he represented them as they appeared to be." This seems to be a paradox; but it is not so, and its meaning and the value of the principle are quite intelligible to artists. It shows that Lysippus considered that very minute detail and close mechanical copying should be made subservient to general effect. Lysippus left several scholars, three of whom, his sons Daippus or Laippus, Bedas, and Euthycrates, are mentioned amongst the most eminent of his successors. The last is said to have imitated the firmness, or the austerer parts, of his father's practice, rather than his more elegant and pleasing qualities. "Therefore," says Pliny ('Hist. Nat.,' xxxiv. 8), "he succeeded admirably in a statue of Hercules at Delphi," &c. There is a fine bronze statue of Hercules in the Townley Gallery in the British Museum, which has every indication of being of this school.

The perfection of sculpture seems to have been attained under Praxiteles and Lysippus. They were contemporary, and each effected in his way what was before wanting to its completion. It is believed that there are imitations of some of the works of Praxiteles in the various modern collections of sculpture. Among these are the Sleeping Faun, at Munich; the Cupid of the Vatican, at Rome; statues of Venus, believed to be copies of the far-famed Venus of Cnidus; and the Apollo Sauroctonus, at Rome.

The death of Alexander the Great (324 B.C.) was followed by the dismemberment of his vast empire. The arts suffered in some measure by these divisions and contentions; but it is difficult to assent to Winckelman's opinion, that after the death of that prince there was nothing left except a class of mere imitators. Each of the artists above mentioned left numerous scholars, who still preserved the high character of sculpture by their own successful practice. Among the most distinguished of these sculptors are Cephisodotus and Eubulus, the sons of Praxiteles; Pamphilus, his scholar; the before-mentioned Daippus, Bedas, and Euthycrates, the sons, and Tisicrates, the scholar, of Lysippus (the works of the latter are said to have been so excellent that they were often mistaken for those of Lysippus himself); Xenocrates, who also wrote a treatise on his art; Chares, the Lyndian, the author of the famous Colossus of Rhodes; Dameas, Eutychydes, and Phœnix. Hermocles of Rhodes is mentioned as having been employed by the earlier Seleucidæ. Isigonus, Pyromachus, and Stratonicus illustrated by their art the victories of Attalus and Eumenes over the Gauls; and the Ptolemies also for a time were protectors and patrons of artists. To the above names many others might be added, sufficient both in number and talent to warrant the belief that sculpture was not only still encouraged and practised on the best principles, but that there were artists living quite capable of aiding its progress by their own genius. The assertion therefore of Pliny (xxxiv. 8), that from the 120th to the 155th Olympiad the art was almost extinct, seems utterly groundless. To this or about this period antiquaries have attributed some of the most interesting remains of ancient sculpture that have reached our times. Amongst these may be noticed the well-known statue of the Hermaphrodite, at Paris; the fine fragment called the Torso of the Belvedere, at Rome; the Hercules, called the Farnese, at Naples; and the statue called the Fighting Gladiator. To these some have added the group called the Toro Farnese, at Naples, representing Dirce, Zethus, and Amphion with the bull, and even the group of Laocoon and his sons.

The fatal blow to the existence of the arts in Greece was given by the success of the Roman arms. Lucius Mummius had been sent by the senate against the Achæans. He engaged the Greek army near Corinth, the principal city of the famous Achæan League, and completely defeated it. The city was immediately devoted to destruction, and sacked by the conquerors. The Romans carried away from this celebrated seat of the arts, as well as from the other cities of Greece which fell into their hands, the greater part of the fine productions both in painting and sculpture, which had been accumulated for centuries. These were forthwith transported as spoil to Rome, which became filled, for the first time, with the most splendid monuments of Grecian taste and genius. This event occurred in the 158th Olympiad, or 146 B.C. Athens, which may be considered as the great centre of art, and the favourite asylum of the most distinguished artists of Greece, had suffered a variety of fortune since the time of Pericles, when her glory may be said to have been at its zenith. Her political importance declined from about that period, but she still seems to have maintained a character as the abode of literature and of art long after her political influence was at an end. At length she was doomed to share, in full, the calamities and humiliations to which other Grecian cities had been subjected by the victories of the Romans. Having vainly endeavoured to impede the progress of the Roman army into Greece, Athens had to submit to what she might fairly consider a barbarian conqueror. In the year 86 B.C. she received as her master the haughty and unrelenting Sulla. The history of ancient sculpture in Greece may be said to close at this time. After the establishment of the Roman empire, the Greeks no longer had either the higher inducements or the means to carry on the exercise of the arts in what may be considered their native country; and their professors were driven to seek employment and an asylum among their conquerors.

The greatest influx of Greek artists into Italy occurred when Augustus had obtained the sovereignty, though earlier than this period there had been some efforts made by individual Romans to introduce a taste for art among their countrymen. A slight general view of what had been effected in this respect, or rather, of the means used to effect this end, will not be out of place here, as introductory to the examination of what has been called Roman sculpture; but the art never appears to have been naturalised among this people, and, as will be seen, it was always rather an exotic in Rome, nursed and tended by its own natural cultivators, Greek sculptors, than a growth brought to any perfection by the people in whose stranger soil it had accidentally, and almost forcibly, been planted.

Roman Sculpture.—It is not easy to determine when the Romans began to pay attention to the arts of painting and sculpture. For a long period they were too much occupied in insuring their safety and strengthening and extending their state, to think of arts which they could then only have looked upon as unworthy of a warlike people. Their first public monuments were doubtless trophies. The trunk of a tree, stripped of its branches, and bearing the arms of the vanquished, proclaimed the achievement of the victor, and at the same time incited the young Roman to exertion in his country's cause. The sculpture mentioned as existing in Rome at a very early date was, there can be no doubt, of foreign growth, the production of their neighbours the Etrurians; and the celebrated she-wolf still existing in the Capitol, one of the most ancient and interesting monuments, whether considered historically, or as an example of early bronze sculpture, may fairly be attributed to that people.

It is recorded that after the victories of Camillus and Mænius over the Latins, equestrian statues were erected in Rome in their honour. This was above 350 years before our era, or about 400 years after the building of Rome. In the 3rd century B.C. one of the Fabii devoted himself to the arts, and acquired, from his success, the surname of Pictor. Pliny ('Hist. Nat.,' xxxv. 4) says that he decorated with his paintings the temple of the goddess of Health at Rome, and that the pictures existed in his time. A bronze statue of Apollo, made out of spoils taken from the Samnites, is said to have been dedicated in the Capitol about this period. After the conquest of Syracuse by Marcellus, Rome became enriched with the spoils which fell into the hands of the victors. The reply of Marcellus, when he was accused of rapacity for stripping the conquered city of its works of art, is remarkable: he declared he had done it in order that the public edifices of Rome might be ornamented, and also to introduce among his countrymen a taste for the arts and elegance for which the Greeks were so distinguished. The power and greatness of Rome were now being extended in all directions; and, by some caprice of fancy, generated probably by the facilities that were offered for its gratification, it became a rage to collect specimens of sculpture. Notwithstanding the opportunities thus offered for acquiring some knowledge of the beauties of art, from the mere habit of having the most exquisite examples of sculpture brought before them, it does not appear that any decided taste discovered itself till about 86 years B.C. Sulla, in his victorious march through Greece, destroyed several of the most magnificent temples and monuments of that country; but he also collected a great quantity of spoil, which he forwarded to Rome, and which consisted chiefly of the fine works which were preserved in the temples or adorned the public places. This enormous accumulation of such objects seems at length to have aroused in the Romans some feeling of admiration favourable to the existence, at least, of art in their own country. The fashion, or rather passion, to form collections at any price increased. Verres is handed down to posterity among the most zealous and at the same time the most lawless of dilettanti; but the character of the works he possessed, several of which are mentioned by Cicero in his celebrated orations against the rapacious prætor of Sicily, gives him a claim to be considered fully capable of appreciating excellence in art. The means that he adopted for gratifying his taste merit the severest condemnation; but he probably preserved from neglect and destruction many of the most valuable monuments of sculpture.

In the last century before Christ various sculptors of distinguished name were resident in Rome, or were practising their art in other parts of Italy. Among these may particularly be mentioned Pasiteles, Arcesilas or Arcesilaus, the author of a group of boys with a lioness; Saurus and Batrachus, Strongylion, Olympiosthenes, and Evander. Arcesilaus was much employed by Lucullus. Strongylion is honourably mentioned for a fine statue of an Amazon, so beautifully formed in the legs that it was called Eucnemos. He also made some statues of Muses; and Pausanias, who alludes to them, adds he was most skilful in his representations of animals. Olympiosthenes also executed three Muses. Pliny speaks in the highest terms of the merit of Pasiteles. He became a Roman citizen, and among his works is mentioned a statue of Jupiter, of ivory, which was placed in the temple (*æde*) of Metullus. It is to be regretted that a literary work of this artist, mentioned by Pliny, no longer exists. He says, "Pasiteles wrote five volumes containing descriptions of the most remarkable works in the whole world." Such a record from an artist of the character of Pasiteles would be a treasure.

Among other fine works in sculpture which are supposed to have been produced in the earlier part of this period, may particularly be mentioned the statue known as the Germanicus of the Louvre. It doubtless is intended for a figure of a Roman: but it seems to be agreed that it cannot be a portrait of the prince whose name it bears, but is of an earlier date. On the pedestal, immediately under the falling folds of the drapery, is a tortoise. As this animal was sacred to Mercury, the god of eloquence, Visconti conjectured that the statue might represent some distinguished Roman orator. A Greek inscription declares it to be the work of Cleomenes, the son of Cleomenes the Athenian; a name distinguished among those who illustrated Greece during the prosperous times of sculpture. The names of Apollonius of Athens, and of Glycon, also an Athenian (the sculptors, according to the inscriptions on the works, of the celebrated Torso and of the (Farnese) Hercules), do not occur in Pausanias; which has occasioned a doubt whether they had executed many works remaining in Greece in the time of that writer. They are thought to have lived in the century before our æra.

Julius Cæsar gratified his taste for the fine arts by collecting statues, gems, and similar objects. His patronage extended itself even to remote places, and he not only embellished Rome, but many cities of Gaul, Spain, Greece, and Asia Minor participated in the advantages of his good taste.

A great impulse was given to the encouragement of sculpture by Augustus. He caused all the finest works that could be procured to be collected, and he had them placed in the public places of Rome. He is also said to have removed the statues of illustrious men from the area of the Capitol to the Campus Martius. (Suet., 'Calig.,' 34.) The example of Augustus was imitated by the wealthy Romans, and no expense was spared in adding new and admired productions to the different collections of statues and paintings. Among the most liberal of the patrons of this period, Agrippa stands pre-eminent for the munificence with which he devoted his fortune to the embellishment of Rome. The Pantheon is a monument of the taste and princely liberality of a Roman citizen. Agrippa employed an Athenian sculptor, called Diogenes, to enrich this temple. Pliny particularly alludes to some Caryatides by him, as well as to some figures in the pediment or front (*fastigio*); but these Pliny ('Hist. Nat.,' xxxvi. 4) says produced less effect, owing to the height at which they were placed. It is recorded that Agrippa constructed some aqueducts, which he decorated with three hundred statues in bronze and marble. During the age of Augustus the names of many very distinguished artists occur. Among them, Vitruvius, the architect, Posidonius, a native of Ephesus, and the celebrated Dioscorides, the engraver of gems, may be particularly mentioned.

The good effect of the example of Augustus seems to have been long felt in Rome, though it does not appear that Tiberius contributed much to preserve or nourish a taste for art. A circumstance however is said to have occurred during this latter reign which shows that the Romans were alive to the value of fine public works. Tiberius admired a statue representing an athlete anointing his limbs, by Lysippus, which stood in the baths of Agrippa—a place, it seems, of public resort. Desiring to have exclusive possession of this work, he had it removed to his own palace; but the dissatisfaction of the people was so great, and their indignation at the emperor's depriving them of what they considered public property so violently expressed, that Tiberius, fearing a revolt, ordered the favourite statue to be replaced in its original situation.

Caligula had works of art brought to Rome from Greece, but it does not appear that he had any admiration of them as objects of beauty or as memorials of an enlightened people, but rather that he considered them as means of gratifying his personal vanity. He ordered the heads of the gods and of illustrious men to be struck off their statues, and his own to be substituted. This paltry ambition, which could be exercised at a cheap rate, accounts for the mutilation of many statues that have reached our times, and in which a totally different character will often be observed in the heads and other portions of the work. Caligula is recorded as the first emperor who was guilty of this species of sacrilege; but he appears to have been imitated by many of his successors. It is a curious fact that, notwithstanding the efforts so unworthily made by Caligula to make himself known to posterity, portraits or busts of this emperor are extremely rare. The reigns of Claudius and of Nero at first gave promise of encouragement to the arts; the latter emperor required decoration for his Golden Palace, which he constructed on the Palatine Hill; and although the vast number of works that had already been procured from Greece would seem to have robbed that country of all its treasures, he procured no fewer than five hundred bronze statues from the temple of Apollo at Delphi. Two of the best works of ancient sculpture, the Apollo Belvedere and the so-called Fighting Gladiator, were found among the ruins of a villa or palace of Nero at Antium. Zenodorus the sculptor was employed by Nero to make a colossal statue of him, of bronze, a hundred and ten or a hundred and twenty feet high. (Plin., 'Hist. Nat.,' xxxiv. 18; Suet., 'Ner.,' 31.) Zenodorus was called to Rome from Cisalpine Gaul, where he had executed a colossal statue of Mercury, a work which had occupied him ten years. Menodorus, an Athenian sculptor, lived at this time. His statues of athletæ, and subjects of that class, are mentioned in terms of commendation. It is probable that there were two artists of this name.

This may be considered the period at which the introduction of variously coloured marbles in statues became the fashion in Rome. The Roman *polylithic* sculpture differed in some respects from that practised by the Greeks. The Roman mode was to imitate the different stuffs of which real draperies were composed, as well as the ornamental dressings of the figures, with marbles (usually Orienta alabasters, &c.) closely resembling them in colour. The Greeks occasionally used different materials, not often marbles, for this purpose; but not with the intention of imitating the particular colour or texture of the object represented. The Romans carried this so far as to express, in white and dark marble, the colours of the eyes in a statue, in black marble, of an Ethiopian. More than one example of this may be seen in the various collections of ancient statues. The reigns of Otho, Galba, and Vitellius were too short and too disturbed to give those emperors time or opportunity to encourage sculpture. Otho ordered a large sum, ninety millions of sesterces, to be appropriated for the completion of the Golden Palace of Nero. Busts of these emperors are extremely rare. There is one of Vitellius in the Museum of the Louvre, of very high merit; but most of the portraits of this prince have been considered modern.

Vespasian, Titus, and Domitian encouraged sculpture. Titus erected two statues, one of gold, the other equestrian, of ivory, in honour of Britannicus, the son of Claudius, who was poisoned by Nero. (Suet., 'Tit.,' 2.) Statues of Domitian are rare, in consequence of the order issued by the senate, after the tyrant's death, that all statues of him should be destroyed.

But little now occurs in the history of sculpture worthy of notice till the time of Trajan. The taste and energy of this prince reanimated the arts both in Greece and Italy. Zeno of Aphrodisias was a sculptor of this time. The column of Trajan is an interesting monument of the art in the latter part of the 1st century after Christ. The reigns of Trajan, Hadrian, and the Antonines may justly be accounted the golden age of sculpture in Rome; though even then it is probable that the art was little practised by native artists. In Hadrian especially the arts found a munificent protector. He restored many of the ancient temples which were falling to decay; he erected others in a style worthy of the best ages of the art; and, among other public-spirited undertakings, completed the temple of the Olympian Zeus at Athens. Among the enrichments bestowed upon it was a statue of Zeus in gold and ivory, several other works placed there by Hadrian, and finally a colossal statue of the emperor himself. The scale of magnificence in which this prince indulged may be estimated from the remains of his celebrated villa near Tivoli, about eighteen miles from Rome. It was embellished with all the finest works that could be procured, whether the productions of ancient Greek artists or of those of his own time. Some of the most interesting and valuable remains of antiquity have been discovered there; and even at the present day every fresh excavation that is made among these ruins restores to the world some object of interest. Some of the Egyptian superstitions having been introduced into Italy about this time, they were mixed up with the existing forms of worship, and the gods of the Nile were admitted among those of the Romans. The example of the capital was soon followed by the smaller communities; and, as the new worship was extended over the whole empire, a great demand arose for statues, and other symbols of Egyptian deities and ceremonies. The imitations of Egyptian figures and subjects which are found in Italy, and which particularly abounded among the ruins of Hadrian's villa, may be assigned to this period.

The numerous specimens of sculpture of the time of Hadrian that are preserved in modern collections are evidence of the high state of the art. The statues and busts of himself, and of the emperors who immediately preceded and followed him, as well as the portraits of Antoninus and Lucius Verus, exhibit qualities that would do honour to the best ages of Greek sculpture. There are two statues of Antinous in the museum of the Capitol, one treated in the Greek style, entirely naked, and the other with Egyptian attributes, which are particularly worthy of notice for the simplicity and beauty united with grandeur that pervades them. They carry us back to the very finest period of the practice of the art.

Sculpture declined after the death of Hadrian. The difference observable, both in style and execution, in the two columns of Trajan and Antoninus, exhibit a marked change in the condition of art, even in the short period that elapsed between the execution of these works. Antoninus Pius was not, however, neglectful of art; but the chief employment of that time seems to have been in portraits and busts, a sure indication of indifference towards the higher class of design.

Herodes Atticus claims a distinguished place in the list of promoters of the fine arts. He employed his immense wealth in embellishing Athens and other cities of Greece. Chryselephantine sculpture was still practised; for it is recorded that he caused a quadriga, with a group of Neptune and Amphitrite, made of gold and ivory, to be placed in a temple of Corinth. By the time of Septimius Severus (about A.D. 200) the arts of design had rapidly declined. The schools for their cultivation, which had been established by Hadrian, were no longer kept up, and the effect of the neglect of pure design is visible in the monuments of this period. The sculpture on the arch of Sept. Severus, in the Forum of Rome, as well as that called the Arch of the Goldsmiths, also at Rome, offer undeniable evidence of the low condition of taste, and the inferiority of practice in art. Considerable care was shown in the littlenesses of execution; but everything that indicated boldness of conception, breadth of treatment, and style, had vanished. With the exception of busts, some of which must be admitted to have great merit, the monuments which remain of the time of Caracalla, Geta, Alexander Severus, and their successors, only confirm the rapid fall of sculpture. Alexander Severus endeavoured to revive a taste for architecture, and even instituted schools for the education of students; but the calamities that disturbed Italy during the contentions for the empire, left men little leisure for elegant pursuits. The degraded state of sculpture in the 3rd century of our era is sufficiently declared by the quality of the bassi-rilievi on the arch of Constantine in Rome; all that were not taken from the arch erected in honour of Trajan's victory over the Dacians, exhibit the utmost poverty of design, with feebleness of execution.

The dismemberment of the Roman empire by the establishment of a seat of imperial government at Constantinople, was a fatal blow to the grandeur and magnificence of Rome; and from this time may be dated the downfall of the city. To Constantine himself some honour is however due for his endeavours to restore a feeling for the arts, by the scale on which he proposed to decorate the new imperial residence. Sensible of the want of artists capable of doing justice to his splendid conceptions, he instituted schools, especially for architecture; and by distributing rewards and giving privileges to students, he endeavoured to induce young men to devote themselves to acquiring a knowledge of the art. He so far succeeded that several considerable buildings were erected, but they were indebted for their decoration to the sculptors of a past age. By the emperor's commands, the cities of Greece and Asia Minor were despoiled of what had been left them by preceding collectors. Statues of gods, heroes, sages, and poets were brought together from all parts, to contribute to the splendour of the new city, and nothing, Cedrenus observes, seemed wanting, but the souls of the illustrious individuals whom these admirable monuments were intended to represent. Some attempts were made to restore sculpture by giving employment to contemporary artists; and statues in metal were erected in this reign and in the subsequent reigns of Constantius, Theodosius, and Honorius; but the spirit of ancient art was lost, and these works, of a totally distinct character from that of the finer Greek schools, appear to have had so little merit, that the names of their authors have not been recorded.

The state of Italy in the 5th and 6th centuries rendered the restoration of the fine arts utterly hopeless. During this unhappy period of her history she suffered from the inroads of the northern nations. In the year 412, Alaric, king of the Goths, ravaged the country and gained possession of Rome. At a later period the city was given up to pillage by Odoacer; and Genseric and his Vandals subsequently added to the destruction. In 545 Rome was attacked by the Goths under Totila; they set fire to the city, which continued burning for several days. In this siege, the Romans, driven to their last hold, defended themselves from the Mausoleum of Hadrian (now the Castle of St. Angelo); and, we are told, threw down upon their enemies the statues which decorated that sumptuous edifice. To the losses occasioned by these and similar means are to be added those consequent upon the anti-pagan zeal of some of the early Christians. They used to drag down the statues of the divinities of the Greek and Roman mythology, and pound them to dust. The finest productions of the greatest masters of sculpture were thus demolished; and so sweeping had been the destruction, that when Arcadius and Honorius issued fresh edicts for carrying on the work of demolition, it was said, "Si qua etiam nunc in templis fanisque consistunt" ("If indeed there should be any still left in the temples").

The greatest treasures of art were preserved at Constantinople, and the palace of the Lausi boasted one of the finest collections of ancient statues. An immense number of these fell a prey to the flames in 479. In the year 661, Constans was driven from Constantinople by the infuriated people, and passed over into Italy. He visited Rome, where he remained a few days, but in this time he despoiled it, as far as he could, of whatever it still possessed of value in art. These works, chiefly in bronze, were carried by his orders to Syracuse, where he proposed to establish himself, and where he died.

The public attention both in the Eastern and Western empire was now too fully occupied with intestine troubles and the attacks of external enemies, to be able to think of the arts. The fury of the Iconoclasts and the conquests of the barbarians forwarded the work of destruction, and though Theodoric, and afterwards Charlemagne, attempted to stop the ravages which were consequent upon the success of their followers, and to afford some protection to the remains of antiquity, their influence was quite inadequate to effect their object or to save the monuments of genius from the violence of an uncivilised and ill-disciplined soldiery. Theodoric (about 500 A.D.) laments, in a letter to Symmachus, the ruin of works of genius, and observes that Rome still possessed a population of statues. Charlemagne formed the plan of renovating art, and most probably would have accomplished his object, if the age had been worthy of the emperor. His great purpose however was to obliterate the remembrance of the splendour of paganism by the magnificence of Christian art; and the entirely new feeling introduced occasioned a totally new style of design, which, as it has little connection with our present subject, will be considered in another place.

The Empire of the West and the glory of the Roman name had passed away. The resuscitation of art and science belongs to another period of our history.

In the 12th century Constantinople, after a series of distresses and difficulties, was taken possession of by the victorious Latins and their allies under Boniface and Baldwin; and the city, which had already been nearly destroyed by a succession of fires, was given over to pillage. Nicetas Choniates has described some of the fine remains of art that were there in his time, and which, during this reign of plunder, were broken or melted down to be coined into money, or sold for the value of the metal. Among them we find various bronze statues of charioteers that stood in the Hippodrome; a group of Bellerophon and Pegasus; Paris presenting the apple to Aphrodite; an exquisite statue of Helen; a colossal Heracles, by Lysippus; and the celebrated colossal statue of Hera, which had once adorned her temple at Samos.

The real history of ancient sculpture may be said to have ended even before the period to which it has here been carried. It is both unsatisfactory and painful to attempt to trace it farther, when each step taken only shows ruin and devastation. The monuments of the Romans are numerous, and have been useful in illustrating ancient writings and in making us acquainted with the manners and customs of that people; but Roman sculpture has not the same claim upon our attention as that of the Greeks. Indeed in following the history of the art in Italy it is obvious that the interest is chiefly kept up by considering sculpture in Rome as a continuation of that of Greece, and not as an art which the Italians cultivated with any original feeling. The best works produced were by Greek artists; and the attempts of the Romans are characterised, if it can be called character, by poverty of invention, meanness of design, and for the most part unskilful execution. The art was seldom patronised but when it was required to flatter the pride or please the vanity of individuals by portrait statues or busts; and consequently it never rose to that excellence or elevation which it attained in Greece, where it was made the means of embodying the grand conceptions of genius by the union of expression and sentiment with the most beautiful forms.

Revival of Sculpture.—After the subjugation of the Greek and the division of the Roman empire, the fine arts gradually declined. Occasionally efforts were made to revive them, but as these arose from individual feeling, and were not supported by any general interest in the subject, the attempt had little success. Charlemagne endeavoured to restore them; but his edicts, unresponded to by the sympathy of those about him, were unable to effect his object. Still the arts were kept alive by the monks of the early Greek and Latin churches, who, with pious diligence, illuminated manuscripts, and sometimes even decorated the walls of their chapels and convents with rude paintings.

It has been usual to date the revival of art in Italy at about the 10th or 11th century. The beginning of modern art may however be reckoned from an earlier time; rather, as Flaxman says, from the reign of Constantine, seven centuries earlier, when Christianity became the religion of the empire. Painting and sculpture then ceased to be employed, as heretofore, on the pagan gods, but were engaged to illustrate subjects connected with Christian worship. Even during the reigns of those emperors by whom the Christians were most persecuted, they ornamented their subterraneous retreats with sacred portraits and subjects from Scripture. (Flaxman's 'Lectures on Sculpture.') The artists to whom the chief merit of reviving art is due, are supposed to have derived no small benefit from the study of the remains of ancient sculpture which were still scattered about Italy, and particularly in Pisa, the native city of the presumed founder of the first school of modern sculpture. Without denying this very probable effect of superior works upon minds just awakening to the beauties of art, it may be disputed whether its influence was so great as some have imagined. It scarcely can be traced where it might most reasonably be supposed to exist, namely, in any peculiarities or finer qualities of style or execution; and it surely must be conceded that the mind and spirit that are observable in the paintings and sculptures of the time of the revival are of an entirely original character and quite independent of the ancient schools. This is remarkable in a class of design which at first seems peculiarly calculated to tempt modern artists to recur to the manner of the ancients, namely, that in which symbols and allegorical figures are employed. In the examples that exist by one of the earliest painters, Giotto di Bondone (chiefly in the Capella dell' Annunziata and in the Salone at Padua), there certainly is no apparent imitation of any of the numerous and varied modes of treating such subjects that were offered to him in the monuments of antiquity. Without the most remote idea of underrating the excellence of fine ancient models, it seems only just to assert a claim for the distinct and original character which divides modern Christian art from that of the Greek schools. A depth of thought, an intention pervades the Christian art, which show an entirely altered feeling; and, after the first period of the rude and almost frightful attempts at design (usually in single figures, gaunt and staring images of the Apostles and saints), the revivers of art seem to have aimed at appealing to the sympathies, rather than gratifying the eye and pleasing the fancy only, by presenting to them beautiful forms. On this ground the artists of this age were essentially men of genius; for, instead of servilely copying, they drew from their own original sources; and the art that proceeded from them eventually became, as was the case with Greek art while master-spirits directed it, great and admirable.

Passing over the performances of the artists who were employed in different parts of Italy in the century before his appearance, Niccolo Pisano may be considered the father of modern sculpture. Many of the artists alluded to united, as was usual in those days, the three professions of painting, sculpture, and architecture, and their works are interesting monuments of their ingenuity; but sculpture only assumed a distinct and appropriate character when the two Pisani, Niccolo and his son Giovanni, devoted themselves to it, and by their talents diffused a love of art throughout Italy. The cathedrals of Pisa, Pistoja, Siena, and Orvieto are rich in the productions of the Pisani. They consist of magnificent marble pulpits enriched with bassi-rilievi and statues, and are evidence of great power both in composition and in deep feeling. An account of these artists and their principal works will be found under Niccola di Pisa, in the Biog Div.

One of the most masterly compositions of any school of sculpture is a semicircular basso-rilievo, in marble, of Niccolo Pisano, representing the 'Taking down from the Cross,' which is placed over one of the side doors in front of the Duomo of Lucca. Another remarkable work of Niccolo Pisano is a basso-rilievo representing the Last Judgment and Punishment of the Wicked, in the cathedral at Siena. His power seems to have been in treating gentle, delicate, or touching representations; but the performance alluded to has great merit for the boldness of the conception, the eager crowding or fearful shrinking of the figures, and for the masterly composition. Niccolo Pisano commenced his profession early in 1200. He lived to an advanced age, and was succeeded by his son Giovanni di Pisa, Arnolfo of Florence, and other scholars. Giovanni executed some esteemed works, but in natural genius he was inferior to his father, and he was satisfied rather to imitate what had been done than desirous or able to advance the art. Sculpture did not make that progress after the death of Niccolo that might have been expected from the merit of his works and the fine opening he had made for its improvement. Arnolfo was much employed both as an architect and sculptor. Two of his works in the latter art, the monument of Boniface and the Tabernacle in the church of St. Paul (fuore le mura), are preserved in Rome. The date of their execution is about 1300, or rather later. Among the more successful imitators of Niccolo Pisano may be noticed Margaritone d'Arezzo, Guido da Como, and "Maestro" Buono.

In the year 1330, Andrea Pisano, the son of Ugolino, who was settled in Florence, executed one of the bronze gates of the Baptistery in that city. The sculpture illustrates the life of St. John. This work is admirable for its beautiful sentiment and simplicity, though it must be allowed to be deficient in the mechanical excellences of sculpture. Andrea Orcagna, contemporary with Andrea Pisano, was an architect, painter, sculptor, and poet. [Orcagna, in Biog. Div.] His works in sculpture, notwithstanding a certain dry quality of execution that pervades them, have great merit. His most esteemed performances are the sculptures on the altar in the chapel or oratory of Or San Michele, in Florence. Orcagna showed great talent in the management of his draperies, preserving considerable breadth in the forms and disposition of the folds, and so composing them as not to conceal the action of the limbs. There are some curious monuments of this early period at Naples, where sculpture was practised by the followers and imitators of Niccolo and Giovanni Pisani. The Neapolitans pretend, indeed, to cite names of sculptors even earlier than the Pisani; and mention is made of "Maestro" Fiorenza and Agnolo Cosentino of as early a date as the 9th and 10th centuries. Approaching, however, nearer to the time under consideration, we find the name of Pietro da Stefani mentioned as a respectable sculptor at Naples. His works are particularly commended for expression, a quality of difficult attainment in what may truly be considered the infancy of art. The two Masucci are also recorded among the sculptors who were at that time decorating Naples with their works. The chief occupation for the artists was in "Depositi," or tombs, monumental sculptures, and occasionally enrichments, in reliefs and small figures, on altars. The monuments were often of a very elaborate kind, uniting sculpture with architecture. Stories of figures in niches, or mixed up with Arabesque or Gothic ornaments, rose one above the other, till, at a certain elevation, the work took a pyramidal form, the apex of which was surmounted by a statue either of the Madonna and Child, or of a patron saint, or sometimes by an equestrian figure of the deceased. There are some very curious specimens of these compositions in many parts of Italy; one of the most remarkable is at Naples, in the church of S. Giovanni dei Carbonari.

The works of Luca della Robbia abound in Italy. They possess merit not only as works of art, but as specimens of a manufacture, or rather, a process, of which this sculptor is said to be the inventor and exclusive possessor. This was the art of covering *terra-cotta* models with a beautiful and peculiar coloured varnish, which renders them as hard as stone. He is supposed never to have disclosed this secret; but there is a tradition that he committed it to writing, and inclosed the paper, or whatever it was inscribed on, in some one of his models, before he sent it to be baked; so that it could only be known at the price of destroying, or at least injuring, a number of his works, till the document should appear. Among his productions are some of great beauty. They consist chiefly of groups, in alto-rilievo, of the Madonna and infant Saviour, or Christ and St. John as children, and similar subjects. Luca della Robbia died in 1442.

In the Gallery of Sculpture at Florence are preserved some extremely interesting specimens of art of this period, by Benedetto da Rovezzano and others. These works merit a careful examination, as they offer not merely valuable illustration of the progress that was being made in the art at the time they were executed, but they possess qualities which claim for them high praise as examples of rich composition and appropriate expression. Many of them are likewise worthy of attention for an approach to great beauty of form, and for the skilful treatment of the draperies.

The next distinguished names which occur in the annals of restored sculpture are those of Lorenzo Ghiberti and Donato di Betto Bardi, better known as Donatello. Ghiberti has secured a lasting reputation by his celebrated bronze gates of the Baptistery of Florence, the edifice on which so many preceding sculptors had been employed. The first gates mentioned by historians were executed by Buonano in 1180: they were destroyed by fire. Andrea Pisano was the next artist employed upon them, and his and the later works at that edifice are fortunately still preserved. The contribution of Lorenzo is in a series of rilievi, ranged in compartments, illustrating subjects from the Old Testament. Michel Angelo is said to have admired them so highly that he declared they were fit to be "the gates of Paradise." Lorenzo brought to this work a great knowledge of composition, a superior acquaintance with the more beautiful forms and movements of the human figure, a refined feeling for expression, and considerable powers of execution. They very far surpass the works of his predecessors in the revival of sculpture, and, in many respects, have not often been excelled. It is not pretended that these reliefs are free from faults. Their chief imperfection arises out of the undefined notions which then existed of the true principles that respectively govern, or should govern, composition in painting and sculpture. It is obviously out of the province of the latter art (which is confined to representing objects by defined forms alone) to attempt perspective appearances and effects which can only be truly and correctly given by aid of colour, or by the skilful distribution of light and shadow. In the work under consideration this principle is invaded. Objects are represented in various planes, and those which should be subordinate are, in consequence of the necessary relief given to them in order to define their forms, forced upon the attention, or cast shadows to the injury of more important features in the design. The number of small parts, and a too great minuteness of detail, are also defects in this remarkable work, and deprive it of that breadth of effect which is so admirable a quality in art. [Ghiberti, Lorenzo, in Biog. Div.]

Donatello was a scholar of Lorenzo de' Bicci, and was born in Florence in the year 1383. The works of Donatello are numerous, and remarkable for their superior qualities. His conceptions were bold, and his execution vigorous, and it is easy to see in his performances the reason for the compliment paid to his statue of St. Mark by one who could so well appreciate these qualities as Michel Angelo: "Marco, perchè non mi parli?" This, and a statue of St. George, also in marble, decorate the exterior of the church of Or San Michele at Florence. The St. George is a fine example of grand and simple expression. The figure, dressed in plate armour, stands firmly on both legs, and he rests his hands on his shield, which is held before him, its pointed base on the ground. There is a calm determination and a quiet dignity in this work. It is probable that the somewhat exaggerated treatment which is observable in this and other productions of Donatello, as well as of Ghiberti, arose from their desire to avoid the dryness and poverty of form in the works of some of their immediate predecessors. [Donatello, in Biog. Div.] Donatello enjoyed a great reputation, and there is scarcely a city of any consequence in the north and middle of Italy that cannot boast some specimen of his talent. He introduced a mode of working reliefs that has not often been practised since his time. The sculptured portion is scarcely raised above the plane of the background. It has the appearance of the design having been drawn on the marble, and then engraved, as it were, under a strong side-light. This kind of work hardly comes legitimately under the name of sculpture, and can only be fitted for certain situations, in which, at a little distance, it has more the effect of a picture than of sculpture.

Brunelleschi, or, as he is called by the Italian historians, Filippo di ser Brunellesco, was contemporary with Donatello. He was an architect as well as a sculptor, and was the originator of the bold idea, which he so successfully carried out, of building the cupola of the Duomo of Florence. [Brunelleschi, in Biog. Div.] Donatello died full of years and honour. He left a brother, Simon, who was invited to Rome by the pope, in 1431. While there he executed one of the bronze gates of St. Peter's. Giovanni di Pisa was another of the numerous scholars of Donatello. There is a large basso-rilievo in terra-cotta by this sculptor over the altar in a chapel of the great church of the Eremitani at Padua, which deserves notice for the simplicity and breadth of the composition, and for the peculiar manner in which it is executed. It represents the Madonna and Child, with three saints on each side, and is remarkable for the flat style of the relief—a mode of working that Donatello frequently adopted, and which, when judiciously managed, has a very broad and fine effect.

Italy was at this time filled with artists, many of them of distinguished merit, who found ample employment in what may be called church sculpture, and occasionally in executing statues of illustrious persons. Florence perhaps boasted the highest names in the several arts, but Bologna, Padua, Milan, Naples, Siena, Venice, Modena, and even the smaller cities of Italy, all had their schools of artists. The Majani and the two Pollajoli, Andrea Verrochio, Andrea Ferrucci, and

Mino da Fiesole, are among those whose works claim attention among the best productions of the 15th century.

Andrea Verrochio is chiefly celebrated as having been the master of Lionardo da Vinci, and of Pietro Perugino, the master of Raffaelle. It is said that Verrochio was at first a painter, but having desired Lionardo da Vinci, then a mere lad, to paint an angel in an altar-piece on which he was engaged, Verrochio found the performance of the scholar so superior to his own portion of the work, that in a fit of jealousy he resolved to paint no more, and he soon after devoted himself to the sister art. A bronze equestrian statue of Colleoni, by Andrea Verrochio, may be seen at Venice in the Piazza di S. S. Giovanni Paolo; it is interesting as a specimen of art of the time, but it is heavy in form, and the action of the horse is not true to nature. Verrochio provided the design and model for this group. It was cast in bronze by Alessandro Leopardo. Several of the works of Andrea are preserved at Florence.

It is a reproach to the artists of the 14th and 15th centuries, that, not satisfied with carrying out their own original ideas, and endeavouring to advance the practice of art within the limits of consistent design, they suddenly had recourse to the incongruous mixture of ancient mythology with the existing religion, an unfortunate innovation which tended to check the steady progress of sculpture by engrafting a totally foreign class of design or ideas upon their own original sentiment; they only misused or abused the one, and at the same time materially injured the effect of the other.

Michel Angelo Buonarotti was born in 1474. At an early age he became the scholar of Domenico Ghirlandajo, the most celebrated painter of his time, and afterwards studied under Bertoldo, the director of the academy established by Lorenzo de' Medici at Florence. The genius of M. Angelo was remarked by Lorenzo, who received him into his house, giving him apartments in the palace, and otherwise honouring him with marks of peculiar favour. As he increased in years, his wonderful powers as an artist were developed; and his powerful and vigorous genius placed him at once in the distinguished station which he still occupies. Till the time of Michel Angelo, the works of art since the revival were all more or less meagre and dry in style, although considerable feeling and talent were occasionally displayed in their conception (or invention) and composition. Extraordinary efforts were sometimes made, as by Ghiberti and Donatello, to infuse into them a better and more elegant quality of form; but it was left to Michel Angelo to effect that total revolution in style which has stamped not only his own productions, but the art of his age, with a character peculiarly its own. The most striking quality in the works of Michel Angelo is an undefinable vastness and grandeur of effect that takes entire possession of the mind. This power is strongly felt in the presence of his colossal statue of Moses, in the monument of Pope Julius II., and of his statues of Lorenzo de' Medici (not "il Magnifico") and Giuliano de' Medici, in their monuments in the family chapel at Florence. The Moses is a grand effort of genius. It is as original in conception as it is masterly in execution. The characteristic feature of this statue is its vast energy; but it is sufficiently tempered to preserve the repose which is essential to true dignity. This work requires to be studied with attention: its merits will then be found to compensate for those minor faults which at first sight offend the fastidious spectator, and which, it must be admitted, the manner of Michel Angelo threw more or less into most of the productions of his chisel and pencil. As a whole, it illustrates the forcible expression applied to the general character of this artist's works, "*Di Michel Agnol' la terribile via.*" The statue of Lorenzo is also seated. He is represented absorbed in thought. He rests his face upon his hand, which partially covers the chin and mouth. The general action is one of perfect repose, and the expression that of deep meditation. It is impossible to look at this figure without being forcibly struck with the *mind* that pervades it. For deep and intense feeling it is one of the finest works in existence. It has been well observed of this statue, that it has no resemblance to the antique, but it rivals the best excellences of the ancients in expression combined with repose and dignity.

In the lower part of the two monuments of Giuliano and Lorenzo, in the chapel of the Medici, are allegorical figures of Day and Night, and the Dawn, or Morning and Evening. They bear the impress of the master-mind and hand; but the violence of action and forced expression of these statues are not in character, in the first place, with the repose which is appropriate to monumental sculpture, and they do not harmonise with the figures above them. The intimate knowledge of anatomy possessed by Michel Angelo, and the evident mastery he had over all difficulties of execution, appear sometimes to have tempted him, as in these statues, to indulge in their display at the expense of propriety of design.

In the Minerva Church at Rome is a much admired statue of Christ by M. Angelo. It has less of violence of action than usually characterises his works; but though it has qualities of a high order, and displays great knowledge of form and skill in execution, it is by no means one of his most successful efforts. The figure wants that calm dignity and refinement which should pervade the representation of the divine nature under a human form. Another work of Michel Angelo, which is often referred to as a specimen of this master, is the statue of David, in the Piazza del Gran Duca at Florence. The powerful hand of the great sculptor is visible in it, and the grand air that is given to the figure by the turn and expression of the head and throat justly claim our admiration; but it is not one of Michel Angelo's finest works. It was executed under very unfavourable circumstances, Buonarotti having been called upon to finish it when the block had already been worked upon by an inferior artist, and considered to be spoiled. In the gallery of Florence is a half-drunken Bacchus, also the work of this sculptor. An ancient subject, it still has the merit of being filled with Michel Angelo's own feeling for character and expression, but it falls short of the manner in which the Greeks would have treated it. It wants purity of taste, and the beautiful form, free from affectation or display, which the ancients knew so well how to apply in all their conceptions. Michel Angelo in this work attempted to represent what he could not feel as a Greek sculptor would, and to this only is to be attributed its inferiority. Among the best known groups by Michel Angelo are the Madonna and Child, in the chapel of the Medici at Florence—unfinished; a Pietà, in a small chapel at St. Peter's at Rome; and a group of Nicodemus supporting the dead body of Christ, with the Madonna and Mary Magdalen. These, as compositions, are of the highest merit. They also abound in pathos, and are in many respects finely executed. The Dead Christ, in the Pietà, is particularly worthy of attention. The tranquillity and perfect repose of death are most successfully shown throughout this figure, and with some slight exception (in the face and in the articulations of the joints, in which the usual exaggeration of Michel Angelo is perceptible), it must be considered one of his finest productions. His works in relief are not very numerous. We possess in this country one in marble, of very great merit, consisting of three figures, representing the Virgin, the infant Christ, and St. John. It is unfinished, but the master is declared in the composition of the group, in the grand style of the forms, and in the bold and vigorous character of the execution. It is in the Royal Academy of Arts, having been bequeathed to that institution by the late Sir George Beaumont, who purchased it in Italy. There is another work very similar to this, and like this also unfinished, in the Gallery of Sculpture at Florence. In the Vatican is another of a different class. It is an allegorical subject, and is a monument of the perfect knowledge of the human figure possessed by Michel Angelo; but it is more remarkable for this than for other qualities requisite in sculpture, namely, simplicity and unity of design. The composition is both crowded and complicated. In taking this rapid survey of some of the principal works of this master, the object has been to bring before the reader the most celebrated of his productions, in order that the accompanying observations might be immediately applied to well-known examples, and the characteristics of his school be more easily understood. Notwithstanding our admiration of the originality of invention, the vigour and mental energy, the knowledge of anatomy, and mastery of execution that appear in his productions in this art, it is generally admitted that the sculpture of Michel Angelo does not give that high satisfaction which is felt in the contemplation of the best works of ancient and some even of modern times. [BUONAROTTI, MICHEL ANGELO, in BIOG. DIV.]

Michel Angelo has had many imitators who have had neither genius nor originality to compensate for the imperfections which are overlooked or forgotten in the mighty inventions of the master-mind, and who for the most part have only been able to copy and increase the faults of his style. Michel Angelo died in 1564, and was buried in the church of Santa Croce in Florence, and a monument is over his grave in which there is a basso-rilievo, by himself, of a Madonna and Child. The design of this "deposito" consists of a bust of Michel Angelo over a sarcophagus, in front, and on each of which are statues supposed to represent Painting, Sculpture, and Architecture. The bust and the statue of Sculpture are the work of Lorenzo, one of his scholars; those of Painting and Architecture are by Valerio Cioli and Giovanni dell' Opera.

There is a group, in marble, in the Chigi Chapel, in the church of Santa Maria del Popolo at Rome, representing Jonas with the sea-monster, which is remarkable for the grand style of its composition, as well as for the breadth and beauty of its forms. It is attributed to a sculptor who lived in the 16th century, called Lorenzetto, but there is a tradition that the design was furnished by Raffaelle, and that he even made the model from which the sculptor executed the marble figure. Michel Angelo had a very high opinion of the works of Beggarelli, a sculptor of Modena, and is said to have exclaimed, on being shown some of his models, "If this clay could but become marble, woe (*guai*) to the antique."

Jacopo Tatti, better known as Sansovino, is more deserving of celebrity as an architect than as a sculptor. [SANSOVINO, in BIOG. DIV.] His chief productions, in both arts, are at Venice. Some statues on the Scala dei Giganti (the Staircase of the Giants), at the Palace of the Doge at Venice, and some bassi-rilievi in other places, especially a bronze gate at St. Mark's, are examples of his ignorance of or indifference to the true principles of design in sculpture, though it would be unjust to refuse them the merit of much elaborate execution. Many of his scholars became distinguished artists. Among them may be mentioned Nicolo Tribolo, Danese Cattaneo, some of whose works are in the church of S. Antony in Padua, Bartolomeo Ammanati, Alessandro Vittoria, a sculptor of great merit, and probably Tommaso Lombardo. About this time a profusion of ornament began to be associated with works in sculpture, and led artists to neglect the simpler qualities of design for high finish and minutiæ of mouldings, flowers, scrolls, and other objects of minor importance. Among the ornamented works of the *cinque cento* which are most worthy of notice, are the splendid altar candelabra in some of the Italian churches. There are some particularly fine specimens of this kind of work at Venice. Baccio Bandinelli, born in 1487, is among the distinguished contemporaries of Michel Angelo, Sansovino, and the great sculptors of that time. [BANDINELLI, in BIOG. DIV.] Although some exaggeration in design and defects in execution may be visible in his works, they possess qualities which claim for their author a distinguished place among modern sculptors. There are some bassi-rilievi in marble, by Bandinelli, round the screen of the high altar in the Duomo of Florence, which are admirable for their breadth and the fine treatment and disposition of their draperies. The fault of his composition generally, whether of one or several figures, is in its too picturesque arrangement, and in his placing his figures in somewhat forced and affected attitudes. The restoration of the right arm of the celebrated group of the Laocoon was entrusted to Bandinelli. Some critics believe this arm should be turned back, and that the hand or some part of the serpent should touch the head of the figure. [LAOCOON.] In Bandinelli's restoration the arm is extended.

There is a work of considerable merit, and also of some interest from the circumstances under which it was executed, in the church of S. Petronio at Bologna. It represents the story of Joseph and the wife of Potiphar, and is the production of Propertia de' Rossi, a lady of great personal beauty, and highly accomplished in various branches of the fine arts. It is said she became enamoured of a young artist who did not return her love, and the disappointment threw her into a languishing disorder which terminated in her death. Her last work was the basso-rilievo above mentioned. In it she represented herself as the wife of Potiphar, and the object of her affection as Joseph escaping from her. She died in the flower of her age, in the year 1530.

Benvenuto Cellini, born in Florence, in 1500, was one of the most distinguished sculptors, founders, and chasers in Italy. All his larger works are in bronze, and are preserved in his native city; but numerous specimens of his skill in smaller productions, as medals of gold and silver, bucklers, dagger hilts, and tasteful ornaments, are in foreign collections and afford ample evidence of the superior talents of their author. The particulars of his life and the history of many of his works are graphically told by himself, in one of the most entertaining autobiographies extant. [CELLINI, BENVENUTO, in BIOG. DIV.]

The list of sculptors of this school, or rather of this division of time (for each effected changes that tended to interrupt the existence or continuance of schools), must close with Guglielmo della Porta, the most skilful of all the artists of Lombardy. He was the scholar of Pierino del Vaga. He was also a favourite of Michel Angelo, from whom he received a very high compliment. Guglielmo had been employed to restore the legs of the famous Hercules (now called the Farnese) of Glycon, which he did so admirably, that when, after a time, the original legs were found, Michel Angelo was unwilling to remove Della Porta's for those which had so unexpectedly been recovered. Della Porta executed few works. The most remarkable, as an example of the influence of the style both of Michel Angelo and of Raffaelle, is the monument of Paul III., in St. Peter's at Rome. Two recumbent statues in this work, one a female of advanced years, representing Prudence, and the other, a young and beautiful woman, as Justice, are particularly fine. The latter figure is deficient in the expression and character proper to the subject, but it is a remarkable performance for the roundness and richness of its execution, and for the knowledge of form displayed in it. This statue was originally naked; since Della Porta's time it has been partially covered with bronze drapery. This artist effected some changes in the process of casting in bronze. [BRONZE.]

At the end of the 16th and the beginning of the 17th centuries, the sculptors aimed chiefly at fine and curious execution. The works of that time exhibit very high merit in many respects, but they are deficient in repose and simplicity. Instead of grace, we find affectation, and mechanical skill was held in higher estimation than what may not improperly be called the moral qualities of art. The works of Giovanni di Bologna, a native of Flanders, but established in Italy, offer ample illustration of this meretricious and destructive taste in sculpture. They are full of imagination, and are executed with a boldness and ability that both surprise us and call forth our admiration, but there is at the same time an exaggeration in the attitudes and an endeavour after picturesque effect that disappoint us. One of the most remarkable performances of this artist is his well-known group, in marble, of the Rape of the Sabines. As a specimen of invention it is wonderful for its expression and its energy of action; and it is impossible not to admire the courage of the sculptor who ventured to execute so daring a work in such a material; but it is open to criticism for the extravagant corkscrew contortions of the composition. His famous bronze statue of Mercury is conceived in the true spirit of poetry, and is deservedly admired as one of the most elegant productions of modern art. The form is light, and the action graceful. He had many imitators, who, like copiers in general, chiefly exaggerated his faults. There are few works of Stefano Maderno, but there is a simplicity of composition and a beauty in the sentiment of his statue of St. Cecilia, that justly claim for him a place among the most worthy of the sculptors of this age. This statue was executed when he was very young. The supposed body of St. Cecilia was found in Rome, in 1599, during the pontificate of Clement VIII., and Stefano Maderno was employed to make a careful copy of it before it was removed to where it now lies, in the church of the convent dedicated to this saint in Rome. This may account in a great measure for the superiority of this work over others by the same artist. Limited by the circumstances, and by the pontiff's command to take nature as his model, he had no opportunity to introduce any of the prevailing bad taste. The result is a work of great beauty, one of the best of that age, and in certain qualities not surpassed by later artists.

Bernini was born at Naples, in the year 1598. [BERNINI, in BIOG. DIV.] He possessed genius, imagination, ambition to excel, unceasing industry, and great powers of execution; and still, with all these means and dispositions, he was, beyond all others, instrumental in precipitating the decline of sculpture; and the tendency, already exhibited, to prefer minute execution to the higher qualities of design, was confirmed by the popularity it acquired in the hands of this artist.

It would be difficult to conceive two styles more opposed to each other than that adopted by the sculptors of this age and that of the great artists of antiquity. In one the pervading principle was simplicity and expression, united with beautiful and appropriate form. In the other, simplicity was of all things most studiously avoided; and complicated arrangement in composition, forced action in the figures, flying draperies, elaborate carving, and undercutting (in works in marble), and other means of little more than mere mechanical display, were resorted to, in order to create surprise or to please the eye. Under Bernini all the distinctive bounds of the classes of art were trampled down. Sculptors endeavoured to imitate the effects of the pencil, and architects to introduce into their compositions the curved line of beauty.

The faults and merits of Bernini as a sculptor will be best shown by a reference to and criticism of a few of his best known works. His group of Apollo and Daphne, in the Villa Borghese, is a production of great merit for its invention and power of telling its story. The god has just reached the object of his pursuit, and, at the moment when he seizes her, Daphne's prayer is heard, and the beautiful form is being metamorphosed into a tree. Instead of generalising this part of the history, Bernini appears to have delighted in the opportunity of showing his skill in execution. The hair and drapery of Apollo are floating in the air, while the change that is to preserve Daphne from violence is shown in detail, in her tresses, the toes and fingers becoming elongated into roots and branches, the latter terminating in carefully-worked laurel-leaves. St. Peter's at Rome contains various works of this artist. The most remarkable of these are the splendid monuments of Urban VIII. and Alexander VII., which may be said to exhibit all his excellences and all his defects. The former stands opposite a celebrated work of Guglielmo della Porta before mentioned (the monument of Pope Paul III.), and is a melancholy proof of the consequences of losing sight of purer principles. Della Porta's was not a school of perfection; but the contrast between the grandeur of manner of his time and the handicraft display of Bernini's period is distressing. The composition of the second work alluded to, the monument of Alexander VII., is as strange as the execution is wonderful. The sitting figure of the pope occupies the centre of a large and deep niche. The whole of the lower part or ground is filled up with curtain and cloud, in the corners of which are plunged four allegorical groups or figures. Of those at the back of the recess but little can be seen except the heads and shoulders. In the front corners are Truth and Charity, the latter a gigantic female, with fleshy infants pressed against her breast, to whose weight the marble appears to yield with all the elasticity of a soft pulpy substance. This work is a triumph of execution, but debased by the worst taste. A group of the Extacy of St. Teresa in the church Della Vittoria at Rome is another instance of the want of simplicity. In this it is difficult, amidst the flutter of the drapery and the ample convolution of clouds, to discover either the figure of the saint or the subject of the composition. The Four Doctors of the Church supporting the Chair of St. Peter, in the church of that apostle at Rome, is a grand idea; but its effect in execution is injured by the want of simple unaffected expression and attitudes. These statues are colossal. They are cast in bronze, and some parts of the figures and draperies are richly gilt. This composition, taking it altogether, has a magnificent effect. Fontana calculated, from the archives kept in Rome, that this work must have cost a hundred and seven thousand crowns. Bernini lived during nine pontificates; from that of Clement VIII. to Innocent XI. No artist ever had greater patronage, and few greater talents, which, unfortunately for sculpture, were ill-directed, or at least ill-disciplined; the variety of his pursuits and his inordinate love of picturesque effect ruined the progress of the art, induced a false taste in patrons and artists, and, from the injury effected by his bad example, it may safely be said that it would have been better for sculpture if Bernini had never lived.

Alessandro Algardi, a native of Bologna, was contemporary with Bernini, and executed many works of merit. Like other sculptors of the time, he was tempted away from the more valuable qualities that should characterise sculpture, by the endeavour to gain distinction by the display of execution and the picturesque effect of his compositions. The great work of Algardi is his alto-rilievo, preserved in St. Peter's, of the discomfiture of Attila by the miraculous appearance of St. Peter and St. Paul. This work is in marble, in five pieces, and measures about thirty feet in height by nearly eighteen in width. Algardi studied the paintings of his contemporaries for the manner of treating his subject; and the consequence is such as might be expected in an art in which it is totally impossible to produce those effects of distance, clouds, and perspective which only can be given by colour. There are merits in parts of this great composition, which increase the regret that is felt at the faults that are so apparent in other portions of it. In the unpleasing task of following the traces of this decay, it is refreshing occasionally to find examples of a purer taste. Francesco di Quesnoy, better known from his title of Il Fiammingo, was a native of Brussels. His early works are said to partake very much of the character of those of Bernini and Algardi; but it is recorded that he was led to copy and study very young children (*putti*), from admiring the beauty of those introduced into his pictures by Titian, and he ultimately became the first sculptor in this class of representation. There are few, whether they have travelled or not, who have not had an opportunity of admiring some specimens of this artist's skill in the round, healthy, playful character of his infants. No artist, except perhaps Raffaelle, ever succeeded so entirely in portraying the peculiar charm of beautiful childhood. He preserved just the right medium between tameness and exaggeration. In the church of La Madonna di Loreto at Rome there is a work by Fiammingo, which represents St. Susanna, and it may fairly be considered one of the most successful efforts in sculpture of the age. The expression of the head is especially worthy of attention. It has simplicity and intenseness combined with considerable beauty of form. Francesco Mocchi obtained a high reputation in his time. The work by which his merits may best be judged of is in the Duomo of Orvieto. It represents the Annunciation, in two distinct figures. The angel is supposed to be descending, and is supported on a cloud; while the Virgin, in an attitude of shrinking modest fear, is bowing her head as she receives his announcement. Its faults are the faults of the age,—a want of simplicity and too much of the picturesque in effect. As examples of elaborate execution, further illustrating the decay of pure taste and the fall of sculpture, the works of San Martino and Corradino may be noticed. Some statues by these artists are preserved at Naples, in the church of S. Severo. One represents the dead body of our Saviour, covered with drapery, under which may be traced all the forms of the figure: a piece of ingenuity of no very difficult attainment, but which always surprises and delights those who are ignorant of the mechanical processes of sculpture, and who think that whatever has the *appearance* of being difficult in art must be so, and measure out their admiration according to their estimate of the ingenuity with which it is overcome. The other is a figure of Modesty, veiled. There is also a third statue, of Deceit, within a net—a very curious piece of execution. These works attest the patience of their respective authors, and are monuments of their bad taste.

The works of the contemporary and immediately succeeding sculptors do no more than prove the rapid consummation of the fall of sculpture. Occasionally an artist of better taste or higher feeling appeared; but he was not seconded or supported by any refined feeling in patrons, nor inciting sympathy in the public, and the enumeration of works by the Rusconi, Bonazzi, Tagliapietra, Torretti, Morlaiter, Foggini, and others, would assist but little in conveying any distinct impression of the slight shades of difference in the generally fallen and decayed practice of the art.

In the general survey of the rise, progress, and decline of sculpture in modern Italy, may be seen, very nearly, the history and condition of the art in other European countries. The artists of Italy spread themselves over the Continent, and wherever works of design were required they probably were called upon to execute them. The influence of the taste of the schools of Lionardo da Vinci, Primaticcio, Benvenuto Cellini, Rustici, and others, will be visible in the works of their different times, in France and other countries; and even when it can be ascertained that sculpture was produced by native artists, it generally will be found that their knowledge of art was due to Italian models or Italian masters.

The French historians attribute to native artists the tomb of Philip le Hardi, which was executed in 1404, as well as that of Francis II. The first sculptor who really was distinguished in that country was Goujon. He executed various important works in the 16th century. Among the most distinguished sculptors of succeeding times may be honourably mentioned Pilon, Anguier, Puget, Girardon, Le Poutre, Le Moine, and Coustou; but sculpture soon became decorative in France, and flutter in composition and design, and minuteness in execution, characterised their art almost from the 16th century to a very recent period. The extreme of the worst style of French sculpture is seen in the monument of Marshal Saxe by Pigal, which was erected about the year 1775.

The earliest sculptors of Spain who are mentioned by their historians of art are Aparicio and Rodolfo, who lived about the year 1033. The next is Jayme or Jacques Castyls of Barcelona, who is said to have executed various statues in the façade of a church at Taragona in the year 1376. The name of Anrique occurs in 1380, and of F. Gonzalez in 1399. It seems, however, that no great progress was made in the arts in this country till the 16th century, when Spanish artists went to Italy to study, or Italian artists established themselves in Spain.

The history of sculpture in Germany would lead us into a wide field of inquiry. It is not necessary towards illustrating the general history of the progress of the art, which may be traced with sufficient accuracy through the different Italian schools; and the examination of the causes of its rise and the changes of style it has undergone amongst the Germans would carry us into speculation, or at best into its merely national or local history, rather than assist us in giving a general and comprehensive view of the art. Läffler, or Löffler, is said to have executed the bronze statues which stand round the tomb of the Emperor Maximilian at Inspruck: he died in 1565. Others attribute them to two brothers of the name of Godi, who lived at the beginning of that century. The latter name suggests the probability that artists from Italy were then established in Germany, or were called upon to execute works of this description.

The political disorders in which Italy was involved in the earlier part of the 18th century, may account in some measure for the inactivity in which the arts remained for some years. The wars of the Succession in the kingdom of Naples, the change of dynasty in Florence in the year 1737, and the unsettled state of other parts of the country, diverted men's minds from such pursuits. Cicognara attributes much also to the debased or degraded state of feeling among his countrymen. But his condemnation is more general and severe than appears to be warranted by facts, and it certainly seems unjust to attribute to the moral degradation of Italians of the 18th century the decline of art which had commenced so long before. It is admitted that, prior to this time, taste in art had greatly deteriorated. The effect of the state of feeling described as existing in this later time was to leave sculpture in its fallen state, when a little energy might possibly have restored it. From 1748 to 1796 Italy enjoyed an uninterrupted course of peace; and it is true that during that period there scarcely was a work in sculpture of any magnitude or comparative excellence produced.

The first sovereign who contributed to revive the arts from this state of torpor was Charles III. of Naples. He encouraged architecture on a grand and extensive scale. At Rome, Cardinal Albani formed a collection of the finest remains of ancient sculpture that could be procured; and by attaching to him all the most distinguished litterati and the best artists of his day, made his palace the resort of all who felt an interest in the pursuits to which he himself was so devoted. Under the auspices of this "Hadrian of his age," as Cardinal Albani has been justly called, Winckelman produced the first work in which the history of the arts of design had been treated in a learned, philosophical, and scholar-like manner; and it has been the model and groundwork of all succeeding and improved works upon the same subject. The popes Clement XII. and Benedict XIV., as well as Clement XIII. and Clement XIV., contributed also to create a feeling for the sculpture of the ancients by accumulating monuments of various kinds in the pontifical palace. To Clement XIV. we are indebted for the foundation of the Museo Clementino in the Vatican, which received such noble additions by the liberality of his successor, Pius VI., that the name of the latter pontiff was associated with that of its founder in giving a title to the collection, and a considerable portion of the gallery of ancient sculpture is still known as the Museo Pio-Clementino. Till Pius VI. issued an order to prevent the removal of works of art, the remains of antiquity discovered in Rome and its neighbourhood could be sold and taken out of the country. The pope, desiring to increase his collection, and preserve to Rome whatever could be recovered by excavation, prohibited anything being removed out of his dominions without a special permission. This order procured for his agents the first choice of whatever statues or other monuments of sculpture were found; and the extensive purchases effected by this means soon filled the Vatican with works of ancient sculpture, which, with the additions made by succeeding popes, have made it the most celebrated, as it is the most valuable, collection of its kind in the world. The discovery of the long buried remains of art in Herculaneum and Pompeii led to the formation of a museum of the same kind at Portici; and, in bronzes especially, the Neapolitan collection is without a rival. Among the sovereigns of Italy who contributed to the revival of design, Leopold, grand-duke of Tuscany, must likewise be included. The sculptors of this period were Cavaceppi, Penna, and a few others, in whose hands sculpture made some progress towards a more healthy state. The immediate influence of the Bernini school had ceased to be felt, and the opportunity was given, which these artists in some degree availed themselves of, to introduce art upon purer principles. It must be admitted that what they produced was eminently deficient in original feeling, and their best works were little more than somewhat tame copies or adaptations of ancient subjects and models; but at least the practice of the art was continued, and when men of greater power and more vigorous minds appeared, they had not to begin afresh from the infancy of sculpture, nor from the miserably low point to which the Bernini manner had reduced it. Before touching upon the most celebrated sculptors who reformed and restored the taste for art in our age, we shall take a rapid survey of the history of sculpture in England.

The Britons had not the advantage of very skilful instructors in the Roman soldiers by whom the country was so long held in subjection;

but during this foreign dominion the native inhabitants had learned to adopt many of the arts. The making of arms and coining money had also taught them some important processes in the more refined arts, and the knowledge thus acquired was not allowed to fall into entire disuse; and it appears that, after the departure of the Romans, the Britons continued to practise some branches of sculpture. Speed (quoted by Flaxman, 'Lect.' I.) says that "King Cadwallo, being buried in St. Martin's Church, near Ludgate, his image, great and terrible, triumphantly riding on horseback, artificially cast in brass, was placed on the western gate of the city," &c. The workmanship of this "great and terrible" statue was doubtless very rude and barbarous, but it is interesting to find the tradition of a work of art cast in brass in this country at so early a date. The death of Cadwallo is placed at A.D. 677.

The edifices erected in England after the final settlement of the Saxons in this country, and down to the reign of Henry I., seem to have been nearly in the same style, exhibiting plain fortress-like construction, and repetitions of heavy columns and arches. Sculpture was so little employed, that it is believed there is no sepulchral statue in England of earlier date than towards the end of the 11th century, though the French had begun to decorate their coffin-lids with figures, &c., as early as the 9th. We may conclude, therefore, that this practice was first introduced into the country at the Norman invasion.

All the oldest monuments in which figures are thus represented are of ecclesiastics. Two specimens of these sculptured effigies, carved in very low relief on coffin-shaped slabs, may be seen in the cloisters of Westminster Abbey. They are supposed to represent two abbots, Vitalis, who died in 1087, and Crispinus, who died in 1117. Similar monuments are preserved in Worcester cathedral, of St. Oswald and Bishop Wulstan. These sculptures, of extremely rude design and workmanship, have been much injured by time and violence, but they are curious as the earliest examples of the kind in this country. It has been thought probable that one reason for not decorating with figures, or any distinguishing device, the stone coffins in which more illustrious persons were enclosed, was to preserve them from the chance of violence which might have been offered to them, in order to gain possession of the ornaments that usually were deposited with individuals of exalted rank. Several monuments of bishops and abbots which have been opened have shown the deceased fully habited in his episcopal robes, with his ring on his hand, and an enriched crozier either lying by his side or across the body. The more sacred character of the occupant of the tomb, and of the objects buried with him, might prevent any indignity being offered to them; but kings and princes would not be considered in the same view, and, as they would no doubt be even more richly dressed than ecclesiastics, however high their rank, their tombs would offer greater temptation to sacrilegious avarice. The circumstance of the tomb of William Rufus in Winchester cathedral being entirely devoid of ornament may be thus accounted for. That of Gundred, daughter of William the Conqueror, at St. John's church, Southover, is inscribed, and embellished with foliage, heads, and other decorations, but there is no figure of the deceased on it.

When the Crusaders returned from the Holy Land, they endeavoured to introduce into England a taste for the magnificence they had witnessed in foreign countries, and imitations were attempted of the rich foliage and other decorations employed in their architecture. In the west door of Rochester cathedral are some figures so applied.

We believe the earliest specimen in England of figures in armour is of the time of Richard I. Those in the Temple church, of Magnaville or Mandeville, earl of Essex, and of two other knights similarly habited, are probably of this date.

The first example that occurs in England of a monumental figure in royal costume is that of king John, on his tomb in Worcester cathedral. An interesting proof that the figures carved on the lids of tombs were tolerably accurate representations of the persons whose remains they contained, was afforded by the opening the coffin of king John in the year 1797. The body, &c., was in a state of sufficient preservation to show that it had been dressed in precisely the same costume as that represented in the sculptured effigy.

Wells cathedral was built by Bishop Joceline, who died in 1242. The west front of this church is richly studded with sculpture, consisting of representations, in relief, of Scripture subjects, and of statues, many of them of colossal dimensions, of kings, queens, saints, bishops, and other patrons or dignitaries of the church. This work must have been in progress at the time that Niccolo Pisano, the restorer of sculpture in Italy, was exercising his art in his own country. Flaxman ('Lectures on Sculpture') thinks that the greater part of the sculpture was by English artists. Some of the statues exhibit much grace and simplicity, and, allowing for the very rude state of art at the time they were produced, they deserve the attention of the curious. The sculpture of the succeeding reign was probably by Italian artists, scholars, or imitators of Niccolo Pisano, who travelled about in search of employment in those countries where ecclesiastical buildings were being erected. The richly decorated crosses that were raised to distinguish the spots wherein the body of Queen Eleanor rested, were probably by these artists, as well as the statues of Edward I. and Eleanor in Westminster Abbey. The flat brasses with figures sculptured, or rather engraved on them, and let into stone slabs, are mostly of the 14th century, few being met with earlier than the reign of Edward II.

Under Edward III. it appears that our own countrymen were capable of exercising some branches of the arts of design. Many specimens of that date remain to prove both the extent to which sculpture was employed, and the merits of the artists by whom the several works were executed. Some interesting examples of art of the 14th century may be seen in three recumbent statues in memory of the sons of Edward III.: one is of the Black Prince, in Canterbury Cathedral; another of Prince William of Windsor, in Westminster Abbey; and the third of Prince William of Hatfield, in York Minster. These works were executed between the years 1344 and 1378. There are also three remarkable windows of this date at Dorchester Church near Oxford: one of them is adorned with between twenty and thirty small statues relating to the genealogy of our Saviour; the others contain reliefs representing Scripture subjects. Various other equally interesting works, exhibiting the progress of the art, belong to this date; and the names of several English artists employed by Edward III. at Westminster are recorded. ('History of Westminster Palace,' by Smith; Flaxman, &c.) The figure, in plate armour, of Beauchamp, Earl of Warwick, on his tomb in the Warwick Chapel, with the numerous smaller statues let into niches around it, is the work of William Austin, an English sculptor and founder. It was executed in 1439.

The chapel of Henry VII. in Westminster Abbey is one of the most beautiful specimens of rich architectural decoration that exists in this or perhaps any country. The statues within and without it are said to have amounted originally to 3000, but the number is probably exaggerated. An Italian artist, Torreggiano, assisted in the construction of this magnificent tomb; but there is strong reason to believe he was employed on the tomb only, and that the greater portion of the sculptures in other parts of the chapel were executed before he arrived in the country, and it is presumed they were the productions of native artists. Some of these statues show a beautiful feeling for art, and are well worthy of attention for the simplicity and grace of their action, and for the tasteful arrangement and careful execution of the draperies.

From the reign of Henry VIII. to Charles I. sculpture fell into neglect. Indeed it frequently happened that, during the religious animosities and the party violence that prevailed, works of art, and more especially works of sculpture, were purposely destroyed. Charles I. showed a strong disposition to encourage the arts. The celebrated Cartoons of Raffaelle were purchased by order of the king, and, with other fine works, were brought into this country. In this reign we meet with the names of English sculptors. Christmas executed a monument to Sir William Pitt and his lady, at Strathfieldsay in Hampshire; and Stone is the author of a monument in Westminster Abbey, in memory of Sir George Holles, which is not without merit. Generally speaking, however, the style and composition of these and other works of the time are utterly worthless, but there is some boldness occasionally in the conception, which may claim for them a passing notice. The sculpture on the pedestal of the Monument of London, representing Charles II., attended by allegorical groups, raising the City of London (under the form of a prostrate female figure), is a striking example of the pseudo-classical and false taste, in art, of the 17th century. After this time, the principal works in England were by foreigners; and the names that most frequently occur are Cibber, Steevens, De Vere, Bertocini, Scheemacker, and Roubiliac, as the authors of monuments and whatever other productions were required in sculpture. This variety of artists, as Flaxman observes, from different countries, — French, Flemings, and Italians, — sometimes brought the taste of Jean Goujon or Puget, sometimes a debased imitation of Giovanni di Bologna and the Florentine school, and sometimes the taste of Bernini, but never a pure and sound principle. In 1766 an English sculptor, Nathaniel Read, executed a monument, which may be seen in Westminster Abbey, in memory of Admiral Tyrrell. It would not be easy to convey by description any just idea of the strange conceits and incongruous imagery that abound in this work; and without the aid of the inscription it would be impossible to comprehend the purpose and subject of the artist's ingenious, and, it may truly be said, costly labours. Admiral Tyrrell died at sea, and his body was committed to the deep. In the lower part of the composition are three allegorical figures, life-size; one of them represents Ireland, as the admiral, we are told, was descended from an ancient family of that country, and above is the apotheosis of the deceased. The 'Historical Description of Westminster Abbey,' after giving the explanatory inscription, notices the work in the following words: "On a piece of rock—'The sea shall give up her dead, and every one shall be rewarded according to his works.' The figures of History, Navigation, and Hibernia are well cut; they are represented among the rocks, with the sea above their heads, the admiral himself ascending amidst heavy clouds." This fully describes the style of the art during the greater part of the 18th century. Allegorical pictures were executed in stone and marble, and it was absolutely necessary to have explanations attached to the work in order to enable the spectator to comprehend the meaning of the sculpture. The monuments contain every variety of a most confined idea; and Time, Fame, and Death, represented in the most absurd, and often most objectionable forms, are made the accompanying illustration to almost every work on which the sculptor was employed.

The works of Roubiliac, with all their defects, have merits which redeem them from this general and deserved condemnation [ROUBILIAC, in BIOG. DIV.]; but, with the qualified exception in his favour, the productions of the artists who practised with him, and after his death, can only be classed in the lowest grade of art; it is impossible to imagine anything more false and poor than the style that prevailed.

Early in the present century, the first step was taken towards forming in England a national collection of ancient works of art. The Townley Marbles were purchased by a grant of parliament, and placed in the British Museum in the year 1808. Since this period the collection has been enriched by the addition of the Athenian (or Elgin) Marbles, the Phigalian Marbles, the Lycian and Xanthian Marbles, the rilievi discovered by Layard and his successors, at Nineveh, and the sculpture still more recently found on the site of the mausoleum at Halicarnassus, together with various fine bronzes, and other valuable specimens of ancient sculpture.

The honour of giving a new direction to taste, or rather, of leading it back to a recognition of true principles, is eminently due to Flaxman and Canova. "To Canova Italy owes her emancipation from those false perceptions which had, from the influence of the Bernini school, so long diverted the current of pure taste. . . . . To Flaxman the art owes equal obligation. Banks had corrected the grosser impurities, and had stemmed the torrent of bad taste." "No modern sculptor has entered so deeply into the recesses of ancient art as Flaxman; his style was founded upon their principles, combined with the simplicity of the Pisani and others of the 14th century." The above short extracts from the address of Sir R. Westmacott, who succeeded Flaxman as professor of sculpture in the Royal Academy, place the merits of these two distinguished artists—the restorers of sculpture—in their true light. In the Theseus of Canova, one of his best and earliest works, we recognise the long-lost purity of form and a decided devotion to the simplicity of the antique. In the designs of Flaxman simplicity, grace, and expression resume their influence, in place of the affectation and display of fanciful ingenuity that had so long prevailed. The later works of Canova show a tendency in that great artist to a more minute execution and attention to small parts than is quite consistent with the best taste in sculpture; and it may be objected to Flaxman, that, in his admiration of the beautiful and impressive in design, he too often neglected the means of making his works effective in execution; but it is not expedient to enter here into a critical examination of their respective merits and defects. Their works, the best evidence of the superiority of these distinguished sculptors, are before the world, and a comparison of their productions with those of the entire series of artists from the time of Michel Angelo (and the best of his immediate followers) down to our own age, will at once exhibit their merit in its true point of view—in the influence they have had in restoring a degraded and fallen art to its proper position.

Mechanical Process of Sculpture.—The technical or mechanical processes of sculpture are for the most part extremely simple. The sculptor, having conceived or invented his subject, usually begins by making a slight sketch of it, either drawing it on paper, or at once modelling it, in small, in clay or wax. This preliminary step enables him to judge of the arrangement, and to correct and improve the general composition of his figure or group. He next proceeds to build up his statue of the desired size. The first thing necessary is to construct a sort of *nucleus*, or skeleton, by which the clay may be supported. This is made of wood or iron, according to the strength required, and the limbs are usually made movable, by attaching the skeleton parts to the main support, or trunk, by wire joints. The figure is then built up in clay; and whether it is ultimately to be draped or not, it should always be modelled naked, in order that the true forms may be easily distinguished, and the drapery made to fall naturally. In modelling in *relief*, a plane, or ground as it is called, is prepared, upon which the sculptor carefully draws his design. The clay is then laid and pressed upon this, the outline of the figures being bounded by the lines of the drawing. The projection or fulness of the forms must of course depend upon the fancy of the artist, or the purpose or situation for which the work may be intended. The same rule with respect to modelling the figures naked should be observed here as in figures or groups in the "round." To preserve the models from shrinking and cracking, it is necessary to sprinkle the clay occasionally with water; and on leaving them, to cover them over with damp cloths.

The next process is "casting." The model being completed, a mixture is made of plaster of Paris and water, which is thrown over the whole. When this is "set," or hardened, the clay within it is picked out, and there remains an exact mould of the model. This is washed, and the interior is brushed over with any greasy substance, usually a composition of oil and soap, to prevent the fresh plaster, with which it is next to be filled, from adhering too firmly to it. After the mould is thoroughly filled in all its parts with this plaster, mixed to about the consistency of cream, the latter is left to set. The mould is then "knocked off" with chisels, and a "cast" of the model is produced entire. If it is intended to execute the work in bronze, the same general principle is observed in the moulding; but there are particular processes to be attended to, in order to enable the mould to bear the weight of the metal, and to ensure the soundness of the "cast." [BRONZE.]

In copying a model in marble, the first step is to prepare two stones of the same size, or at least with an exactly corresponding graduated scale marked on the front of each, on which the block of marble and the model are respectively to be placed. The fronts of the two scales are so constructed or fitted up, that a "pointing" instrument can be applied to them. This instrument is usually composed of a pole or standard, to which a long brass or steel "needle"—capable of being extended and withdrawn, loosened or fixed, and moved in every direction by means of ball-and-socket joints—is attached. This is made to touch a particular part of the model. The whole instrument is then removed to the scale-stone on which the rough block is placed, and the marble is cut away till the needle reaches as far into the block as it had been fixed at upon the model. A pencil mark is then made upon the two corresponding parts of the model and block, and thus what is technically called "a point" is taken. This process is repeated till the numerous points at fixed depths, corresponding throughout with the surface of the model, are attained, and a rough copy of the sculptor's original work is thus mechanically made. These instruments for pointing marble statues are not always constructed in precisely the same manner. The practice of different sculptors has suggested various changes in detail, by which either the movement of the whole machine from one scale-stone to the other is facilitated, or a greater rapidity and security in taking points is attained; but the principle on which they act seems to be exactly similar in all. The statue being rudely blocked out or pointed, the marble is in this state put into the hands of a superior workman called a carver, who copies the minuter portions of the work, by means of chisels of various sizes, rasps, and files; the pencil marks or points showing him the limits beyond which he is not to penetrate into the marble. When the carver has carried the work as far as the sculptor desires, he proceeds himself to give it the finishing stroke, by retouching and improving the details of form and expression, by producing varieties of texture and surface, and by giving that general quality or appearance to the whole which constitutes what is termed harmony of effect.

SCURF is a material composed of minute portions of the dry external scales of the cuticle. These are, in moderate quantity, continually separated by the friction to which the surface of the body is subject, and are in due proportion replaced by others deposited on the inner surface of the cuticle. Sometimes, however, they separate in unnatural quantities, and this constitutes the disease called Pityriasis.

Pityriasis (from *πίτυρον*, bran) is a disease of the skin in which irregular patches of the cuticle appear covered with thin bran-like scales, or with particles of a fine white powder, which, as fast as they fall off, are succeeded by others. It may be regarded as a morbid excess of the natural process of desquamation which is constantly going on, and by which the old cuticle is removed from the surface of the body to be replaced by that of more recent formation. The commonest form of this disease is that called *Pityriasis capitis*, or dandriff. It affects chiefly the scalp and eye-brows, and is most frequent in children, in whom it originates either from generally disordered health or from mere neglect of cleanliness. It occurs also on the face and sometimes on other parts of the body in adults and old persons after exposure to the sun or a cutting wind, and it usually accompanies the commencement of baldness. The only local treatment which is necessary or useful is frequent washing, and the application of some mild and simple ointment.

In the other forms of pityriasis the discoloration of the cuticle is a more prominent sign than its desquamation in fine scales. *P. versicolor* occurs in the form of irregular yellow or light brown patches, which are chiefly situated on the front of the chest and abdomen, and are commonly called liver-spots or tan-spots. The extent and form which such spots present are infinitely various; but though they sometimes exist unaltered for several years, they rarely produce any inconvenience beyond a slight itching. *P. rubra* is an aggravated form of the preceding; the spots are more or less brightly red, and are the seats of considerable irritation. In *P. nigra* the essential part of the disease, which is of very rare occurrence, is the production of a cuticle of nearly a black colour.

SCURVY. This word, as well as its Latin synonym *scorbutus*, has been used very vaguely, both by medical men and by the public at large, to designate various diseases of the skin, often differing essentially from each other. Its derivatives, *scorbutic* and *antiscorbutic*, of which the former is employed to designate a supposed virus, the source of these diseases, and the latter the remedies employed for their cure, have been misapplied in a similar manner.

Scurvy, properly so called, is a malady of a peculiar nature, which occurs either at sea or on land as the result of various moral and physical causes of disease, especially of deficient nutriment and a scarcity or total deprivation of succulent vegetables or fruits. Its origin is involved in obscurity, and it is a question still debated whether it was known to the Greeks and Romans. Of its prevalence in the middle ages we have abundant testimony, but the frequent famines that resulted from the imperfect state of agriculture at that day gave rise to so many diseases, which, though different, yet had many points of resemblance, that we run considerable hazard of confounding them. Thus there is a great similarity between scurvy, the disease which was then called St. Anthony's fire, ergotism (the peculiar disease produced by spurred rye or other grain), and some of the pestilential fevers of the middle ages, both in their causes and symptoms, and there can be no doubt that the chroniclers of those times often mistook one for the other. It is customary to fix upon the year 1260 as the date of the first authentic mention of the malady, which then appeared in the Christian army during the campaign of St. Louis in Egypt. In the north of Europe, however, it would seem that scurvy has been known from the most remote antiquity, and until within the last two centuries it prevailed there endemically. With the improvements in gardening and agriculture, it gradually became less frequent. As late as the middle of the last century it was common not only among the peasants on the borders of the Baltic, but it prevailed in Scotland and in some of the sea-port towns of Devonshire and Cornwall, breaking out in winter, and disappearing as vegetable food became more abundant with the return of spring. Later the disease has occurred in camps, as in the French army of the Alps at the close of the last century; and in besieged towns whose inhabitants have been deprived of fresh vegetables. A famous French physician, M. Foderé, mentions that isolated cases occur every year in the more unhealthy quarters of Paris. Some of its earlier symptoms may occasionally be observed in patients admitted into the London hospitals; and our prison reports prove it to be by no means uncommon in persons sentenced to long periods of confinement. Diseases are still endemic in various parts of Europe, which present a great analogy to scurvy both in their causes and symptoms; such as the Radesyge in Norway, the Mal de la Rosa in the province of Asturias in Spain, and the Pellagra in Lombardy.

During the prevalence of the potato disease in Ireland, in 1845, scurvy prevailed extensively. It was occasionally observed at the same time in most of the large towns of England, and since, when potatoes have been scarce, it has been known to break out. During the Crimean war, it prevailed extensively, both among the French and English troops.

But it is at sea that the ravages of scurvy have been most severely felt, and any one at all familiar with the accounts of our early navigators must remember many heart-rending tales of suffering which they record. Even as recently as the time of Lord Anson scurvy was so fatal that during the first two years of his voyage he lost more than four-fifths of his original crew. The sagacity of Captain Cook however, only thirty years afterwards, suggested to him such means for the preservation of the health of his ship's company, that in a voyage of more than three years only one sailor of the Resolution died. The name of Captain Cook is now frequently mentioned in connection with his successful voyages, but his claim to the gratitude of posterity may be fairly grounded on the wonderful sanitary results of his voyage round the world.

The improvements which, at the suggestion principally of the late Sir G. Blane, were introduced into the victualling of the navy at the end of the last century, and especially the free employment of lemon-juice, have banished this disease from our navy, though it is still by no means infrequent in the merchant service.

The use of salt provisions has been very generally regarded as one of the most powerful exciting causes of scurvy. This notion, however, is not altogether free from error, for scurvy occurs even among those who never taste salted food. Such was the case with some of our troops quartered in the province of Adelaide at the Cape of Good Hope, among whom scurvy appeared in the year 1836. The men at that time had no hard duty to perform, and were supplied with fresh meat in abundance, but were deprived of vegetables. The annual occurrence of scurvy among the inmates of the lunatic asylum at Moorshedabad in India is an additional confirmation of the same fact. We may with more propriety refer the disease to the absence of vegetables than to any directly injurious effects produced by salt provisions.

The greatest attention to ventilation was not found during Lord Anson's voyage to diminish the severity of the disease; and this circumstance, coupled with other facts, such as the non-occurrence of scurvy in the ill-ventilated houses of the poor in London, warrants the conclusion that impure air is not an exciting cause of scurvy.

Some facts have led to the supposition that cold and moisture tend much to produce scurvy, but Dr. Budd, in his able treatise on scurvy, in the 'Library of Practical Medicine,' states that the men admitted with scurvy into the Dreadnought hospital-ship come almost exclusively from the Mauritius, India, Ceylon, or China. The non-existence of scurvy at Venice, and in other similar situations, proves that moisture alone cannot produce the disease.

It has been asserted, but never satisfactorily proved, that scurvy is propagated by contagion; an opinion which is now usually regarded as erroneous.

From all investigations, we may conclude that there is one condition which never fails to produce scurvy in persons, however various their situations may be in other respects, namely, a prolonged abstinence from succulent vegetables or fruits, or their preserved juices, as an article of food. But we are hardly warranted in asserting, as some men of eminence have done, that a deficiency of vegetable food is the only cause capable of producing scurvy. A disease very similar to scurvy, which used to attack the negroes in the West Indies, was attributed to their living exclusively upon bananas, and its cure consisted in changing their diet, and giving them fish and flesh to eat. Bad nutriment, of whatever kind, will, according to M. Foderé, sometimes produce the disease, and Dr. Henderson, a naval surgeon, recently stated in a medical periodical, that he has seen scurvy occur in persons who were taking daily doses of lemon-juice as a prophylactic against the disease.

From these facts Dr. Garrod was led to suppose that the real cause of scurvy was some deficiency in the food which was supplied by vegetable diet. Having examined the constituents of food that produced scurvy, he was led to conclude that such food was deficient in potash. Having analysed those vegetable foods which prevent and cure scurvy, as potatoes, water cresses, cabbages and lemon-juice, he found in all these a considerable quantity of potash. It is difficult to test this theory by withholding vegetable food and administering the salts of potash to patients afflicted with scurvy. It has, however, this characteristic of a true theory, that it explains the phenomena of the cure of scurvy by the addition of fruits or vegetables to the diet.

It was at one time supposed that the citric acid of the lemon-juice was the active cause of cure in cases of scurvy, and when this acid was separated it was substituted in the navy for the lemon-juice, but it entirely failed to arrest the disease.

Previous debility appears to predispose to scurvy, as does also an advanced age; the disease being rarest between twenty and thirty years of age, though it occurs more frequently between the fifteenth and twentieth year than in the succeeding ten years. The first symptoms of the affection are a change of the natural healthy complexion to a pale or sallow tint, accompanied with pains in the legs and loins, great languor and despondency, and indisposition to exercise. The gums soon become sore, apt to bleed on the slightest touch, livid and spongy. As the disease progresses the debility becomes greater, the slightest exertion inducing breathlessness and palpitation, and the complexion assumes a brownish or dingy hue. The gums become more livid, and swell more, so as sometimes to conceal the teeth, which drop out without undergoing decay. Hæmorrhage takes place from the lungs and from various internal organs, ecchymoses appear, and blood is effused under the skin in various parts, especially on the lower extremities and around the seat of any old injury. In the ham this effusion of blood is sometimes so considerable as to cause contraction of the knee-joint. Any wounds or ulcers put on an unhealthy appearance, and become covered with coagulated blood, and the slightest scratches degenerate into troublesome sores. In high degrees of scurvy, as in the case of Lord Anson's sailors, old wounds break out afresh, and a broken bone will become disunited, although the fracture may have been consolidated for some time. With these symptoms there is not so much derangement of the general functions as might be expected. The appetite usually continues good, though the patients are unable, owing to the state of their gums, to masticate their ordinary food; they sleep well, and the intellect is unaffected, though the spirits are much depressed. Scorbutic persons swoon readily, and not unfrequently die suddenly on making some more considerable exertion than usual.

If the disease should prove fatal, discoloured spots are found in many internal organs, while their tissue generally is of a paler colour than natural. The blood contains a less quantity of red particles than usual, but they are not dissolved in the serum, as some have supposed.

SCUTAGE. [Escuage.]

SCUTELLARIN. A bitter matter of unknown composition found in the *Scutellaria lateriflora*.

SCY'TALE (σκυτάλη, a stick) is the name of a secret mode of writing which was used by the ephors at Sparta in their communications with their kings or generals when abroad. The ephors cut the material upon which they intended to write into one long stripe, like a narrow riband, which they wound about a round staff so as to cover the whole. The command or communication which they had to send was then written upon it, and then the slip of writing material was taken from the staff and sent to the king or general. The slip appeared only covered with single letters, which none could read unless he wound the slip around a staff of precisely the same size as that used by the ephors. Kings and generals therefore, when they went abroad, were provided by the ephors with a staff precisely like that which the ephors themselves intended to use in their communications with them. (Plut., 'Lysand.,' 19.) This rude mode of sending a message must have originated at a very early period, but no instance of it is recorded previous to the time of Pausanias. (Corn. Nepos, 'Paus.,' 3.) After the Peloponnesian war, we find the Spartans using the scytale also as a medium through which they sent commands to their allied cities. (Xenoph., 'Hist. Gr.,' v. 2, 37.)

SCYTHE. The common scythe is an instrument too well known to require a minute description, but as much of its utility in agriculture depends on a correct adjustment of its parts, we shall briefly advert to them. The blade of the scythe, which is always curved, with the cutting edge on the concave side, is fixed to the handle at an angle both to the plane of the blade and to the tangent to the curve. It is on the nice adjustment of these angles that the perfection of the instrument depends. A scythe must cut the corn or grass, especially the latter, as near to the ground as possible; and where the land lies flat and the stones have been removed from the surface, a good scythe, in the hands of a skilful mower, will cut the grass so near to the ground that little or no stubble is left. Every farmer knows well that an inch of the grass near the ground adds more to the weight of the hay than several inches higher up, and that a skilful mower with a good scythe can easily add much more to the value of the crop than his earnings amount to, however liberally he may be paid, and that it is of the greatest importance that none but the best mowers be entrusted with the work, and that attention be paid to the form of their scythes and to their being frequently whetted.

It is the custom in England for the mowers to stoop much in mowing, by which they imagine that they have a wider sweep. The angle at which the handle is fixed is very acute to the plane of the blade. In other countries the mowers stand more upright, and a longer handle gives them a greater radius. Habit makes that position easier to which we have been long accustomed; but it is probable that a man can endure fatigue, and continue his exertion the longer, the more nearly his position is erect. In some countries the handle of the scythe is nearly straight, and the end of it passes over the upper part of the left arm. The position of the mower is then nearly erect, and his body turns as on a pivot, carrying the blade of the scythe parallel to the ground, and cutting a portion of a considerable circle. The position of the handle in this case must be such that when the scythe is in the middle of its swing, and the blade parallel to the ground, it rests naturally on the left arm above the elbow, while the mower is nearly in an erect position. By turning his body to the right, and stooping towards that side, he begins his cut, and by raising himself up, the muscles of his back greatly assist in swinging the scythe round.

The blades of the scythes on the Continent are mostly made of natural steel, such as is found in parts of Germany, and they are so soft that the edge can be hammered to sharpen it and keep it thin. In England the scythes are forged thin and well tempered, and to prevent their bending they have a rim of iron along the back to within a few inches of the point. This saves much time in sharpening, and they very seldom require the grindstone.

Most scythes have two projecting handles fixed to the principal handle, by which they are held, and these are variously put on, according to the fashion of the district. The real line of the handle is that which passes through both the hands and ends at the head of the blade. This may be a straight line or a crooked one, generally the latter, and by moving these handles up or down the main handle, each mower can place them so as best suits the natural size and position of his body. Hence it is that a man can seldom mow well with another man's scythe.

In mowing corn when ripe, which is an economical mode of reaping, the scythe need not have so great a sweep, nor is it necessary to cut the straw so near to the ground. The great difficulty here is to lay the cut corn evenly, so that the binders can readily collect it and tie it into sheaves. This is most effectually done by adding to the bottom of the handle a small hoop at right angles to the line of cutting, and by mowing always towards the standing corn, which is easily done by beginning at one end and going round toward the left in an irregular spiral to the centre of the field. The straw is thus laid leaning against the standing corn, and is readily collected with the arm by the binder, who follows the mower. As the straw is not always upright, but frequently bent to a side, this mode of mowing is not always practicable. When the corn is only slightly bent down, a scythe with an addition of a cradle, as it is called, collects the slanting straw more easily. The cradle is a species of comb, with three or four long teeth parallel to the back of the blade, and fixed in the handle. This inserts itself behind the straw to be cut, raises it up, and by a peculiar twist of the scythe after the stroke, it is left so as to be easily collected. Those who are accustomed to use the cradle-scythe do the work rapidly and well.

When the corn is much laid and entangled, it is impossible to use the common scythe, even with a cradle. This has probably suggested a scythe to be used with one hand, while a hook in the other gathers the straggling corn. The most perfect of these scythes is called the *Hainault scythe*, from a province of that name in Belgium, where it was first noticed. It is commonly used in different parts of the Continent. The Hainault scythe is swung by the power of the wrist principally. It does not cut the straw by so oblique a stroke as the common scythe, but rather as a bill-hook or axe would do, meeting the straw nearly at right angles. The hook collects a small bundle, which is severed at a stroke, and the left foot assists in holding what is cut and rolled together with the hook, in the hollow of the blade. It is thus laid aside, and fit to be tied up. This instrument is a great improvement on the English fagging-hook, which is used in the same manner, the left arm of the reaper acting the part of the hook; but as the handle is inserted in the plane of the blade, it causes the reaper to stoop low, which is fatiguing to the loins, especially of elderly people, who can more readily reap with the Hainault scythe.

The scythe is an instrument which should be more generally introduced in harvest, and experience has proved that it had many advantages over the sickle or reaping-hook. [HARVEST.]

SEA and OCEAN are terms by which the whole volume of water is designated which occupies the lower portion of the surface of our globe, and thus separates the solid and more elevated masses which are called land, and which rise above the level of the sea.

Sea-water has a salt and somewhat bitter taste, and in its natural state is unfit for drinking or for culinary purposes. Its specific gravity is about 1·0277, rain-water being 1·0000. The water of closed seas into which many rivers fall is lighter, as that of the Baltic, which is only 1·0067, and that of the Black Sea. But the water of the Mediterranean is more salt than that of the Atlantic Ocean. In those parts of the ocean which approach the poles the water is of less specific gravity than in those parts which lie towards the equator, which may be due to the melting of the enormous masses of ice which are found in the higher latitudes.

Sea-water has repeatedly been analysed; the latest results are stated under SODIUM. That of the Baltic contains only 1·18 per cent. of salt, but the water of the Mediterranean contains 4·18 per cent.; the former being considerably below and the latter somewhat above the average of the oceanic water. The sea is therefore a weak brine, from which the salt may be extracted by the heat of the sun and dryness of the climate.

Besides mineral substances, sea-water contains a slimy fetid matter, which imparts to it a nauseous taste, and which is probably the produce of the decomposition of animal and vegetable substances, which abound in the sea. It has been observed that the sea-water, when not agitated for a long time, is very subject to pass into a certain state of putrefaction, and in that state it exhales very unpleasant odours, which are a real nuisance to the seaman. It is likewise known that some low coasts between the tropics are subject to diseases, which are attributed to the miasma arising from the sea after a long continuance of calm weather.

It has often been maintained that sea-water has no colour, but it is well known that the sea at a great distance from the land has an exceedingly fine ultramarine tint, which cannot be considered due to reflection from the atmosphere, as the colour of the sea is frequently of a deeper hue than that of the sky, and does not change even when the sky is covered with clouds. This colour undergoes some changes in shoals, where it is modified by the colour of the matter which forms the bottom. The greatest variety in the colour of the sea seems to occur in the Greenland Sea, between 74° and 80° N. lat., where it varies from ultramarine to olive green, and from the most perfect transparency to deep opacity. The green colour is liable to changes in its position, but still it is always renewed near certain situations from year to year. According to Scoresby, from whom we take this account, it frequently constitutes long bands or streams, lying north and south, or north-east and south-west, but of various dimensions, sometimes extending two or three degrees of latitude in length, and from a few miles to ten or fifteen leagues in breadth. This occurs very generally about the meridian of London, and the whales chiefly feed in this green-coloured water. When examined by Scoresby, it was found to be replete with minute animals, principally Medusæ, to which its colour was due.

The transparency of the sea-water seems to be connected with its colour. It is much greater than that of river-water, which contains much heterogeneous matter in suspension. It has been said that the light penetrates to about the depth of 60 feet only, but this is a vague estimate, requiring much qualification; some rays certainly penetrate much deeper. This transparency of the sea-water increases with the distance from the shores, and is generally greater in the higher than in the lower latitudes, which may arise from the circumstance that the number of organic substances in the sea is much greater in warm climates. But there are many remarkable exceptions to the last-mentioned fact. Some parts of the sea between the tropics are distinguished by the transparency of their waters, especially the Caribbean Sea, where zoophytes and sea-plants, though growing on a bottom twenty or thirty feet deep, appear to be near enough to the surface to be plucked by a person in a boat; indeed some navigators affirm that the bottom of the sea may be seen at the depth of 150 feet. In the northern seas indeed it is asserted that the bottom may be seen at the depth of from 400 to 500 feet.

One of the most remarkable properties of sea-water is a certain luminous appearance, which has been observed in all seas, but appears in its greatest splendour between the tropics. In calm weather, when the water is moved by the motion of a vessel, the light assumes the form of brilliant stars, or round masses of a greenish hue, frequently eighteen inches in diameter. They float by the vessel in every part of the water which her bottom has touched, as deep as the lowest part of her keel, and form behind her a long and fiery train. At other times, when the breeze is strong, and the billows break and foam, the light appears like fields of flashing fire, through which the vessel is making her way. When the night is dark, the brilliancy of the water forms a beautiful contrast with the black concave of the sky; but as soon as daylight returns, the splendour disappears, and the sea exhibits only its usual dingy colour. At night, the slight agitation of the water occasioned by the action of a steady breeze upon the surface is generally sufficient for producing it. We are entitled to believe, as the result of modern scientific research, that this phosphorescence of the ocean depends exclusively on the presence of myriads of marine animals and animalcula, having the power of producing *animal light* (as animals higher in the scale of organisation produce *animal heat*);

unless, indeed, the conjecture of Professor Schönbein, that it partly arises from the oxidation of dead organic matter in the sea by means of ozone, should hereafter be verified. The luminous animals belong to every sub-kingdom of invertebrate animals: Protozoa; Radiata, especially the Acalephæ; Crustacea, as a class of Annulosa; Mollusca; and the osculent groups of the Annelida and Tunicata; some of the compound forms of the latter, or compound Ascidians, being among the most splendidly phosphorescent. In the Transactions of the Berlin Academy of Sciences is a valuable paper by Ehrenberg on the luminous animals of the sea, containing a copious list of the species observed to possess this property. [LUMINOSITY OF ORGANIC BEINGS, in NAT. HIST. DIV.]

From the well-known laws of gravitation, it is inferred that the surface of the sea is always at the same distance from the centre of the earth, and that consequently it forms a uniformly regular curve. This surface of course maintains the same level, and it is consequently the best basis from which to determine the relative elevations of the different parts of the land. Some facts bearing on this subject, and on the precautions requisite in the use of the sea-level as a *datum* line, are stated near the end of this article, where the physical changes of the sea are noticed. But though the surface of the sea is a regular curve, minute investigation has shown that there are some irregularities, and that some parts of the sea are more elevated than others. This is particularly the case with closed seas, which are generally more elevated than the ocean. The level of the closed seas is higher than that of the ocean when the mass of water brought to them by the rivers which discharge into their basin is greater than that which is lost by evaporation, and the straits by which they are united to the ocean are not wide enough to carry off the surplus waters quickly. On the other hand, when the evaporation is greater than the supply of water from rivers, the level of the closed sea sinks below that of the ocean, and it must be supplied with water from the latter by the straits which unite them.

The Baltic, though of no great extent, and though united to the open sea by three straits, one of which is of considerable width, receives so great a supply of river-water, that its level is higher than that of the North Sea. Very exact measurement has shown that this difference amounts to more than a foot between the level of the North Sea near the mouth of the river Eider and that of the Baltic near the town of Kiel. It is true that when the level of the North Sea has been raised by a continuance of western and north-western winds, a current sets from the Cattegat into the Baltic, but in calm weather it is always found that the current sets northward through the three straits. The difference of level between the Black Sea and the Mediterranean is much greater. The large rivers which fall into the Black Sea bring down an immense volume of water; and accordingly a very strong southern current is constantly found to be setting southward through the Strait of Constantinople into the Sea of Marmora. It generally runs with a velocity of about three miles an hour, which however at one place, called the "Devil's Current," is much greater, and at times between five and six miles per hour. The velocity of this current must vary with the seasons; for it is stated that the level of the Black Sea in winter is between two and three fathoms higher than in summer. The Sea of Marmora, which thus receives the surplus of the waters of the Black Sea, must also be more elevated than the Mediterranean; for the current which sets through the Strait of the Dardanelles is likewise constant and rather quick, though not so quick as that in the Strait of Constantinople.

The Mediterranean, on the other hand, receives a very scanty supply of water by rivers; for with the exception of the Nile, no large stream falls into its basin, which is of much greater extent than that of other closed seas, and therefore it must lose a great volume of water by evaporation. Halley showed that the Mediterranean, whose temperature is from 4° to 5° Fahr. higher than that of the Atlantic under the same latitude, must lose by evaporation nearly three times as much water as is brought into it by the rivers. The deficiency is supplied in two ways: by the current of the Dardanelles, which brings to it the surplus waters of the Black Sea and of the Sea of Marmora; and by that which sets through the Strait of Gibraltar from the Atlantic Ocean. The Atlantic current runs somewhat more than one mile and a half per hour. It has been supposed that, though this current constantly sets into the Mediterranean, an under-current runs in an opposite direction, carrying back a portion at least of the water to the Atlantic; but the attempts which have been made to establish this fact have failed, and it is probable that this supposed under-current does not exist. Notwithstanding the large supply of water which the Mediterranean receives at its two extremities, the level is below that of the Atlantic. Corabœuf found that the difference of level on the Mediterranean near Perpignan, and on the Bay of Biscay near Bayonne, amounted to nearly six feet; and Délambre and Mechain found it to be nearly three feet between the North Sea at Dunkerque and the Mediterranean near Perpignan.

In these instances the difference of level is satisfactorily explained; but the explanation is not so easy with respect to the great difference between the level of the Mediterranean and that of the Red Sea. These two seas are separated by the Isthmus of Suez, which extends about 70 miles from north to south. When the French occupied Egypt, they executed an extensive levelling across this isthmus; and the result was, that the Red Sea is above 32 feet higher than the Mediterranean. No river of importance, not even a perennial stream, falls into the Red Sea, which must also lose a considerable volume of water by evaporation. This loss of water is probably supplied by the current which sets into the Red Sea from the Indian Ocean; and some persons are of opinion that the difference of level between the Red Sea and the Mediterranean might be produced by this current. But it seems improbable that such an effect can be produced by this cause. According to Horsburgh and Wellsted ('Journ. of Lond. Geogr. Soc.,' vol. vi.), a current sets from the Indian Sea into the Red Sea between October and May, and it often runs with great rapidity. But between May and October the northern winds prevail through the whole extent of the Red Sea; and these winds, which frequently blow a gale, cause a continual current to set through the straits into the Gulf of Aden. Under such circumstances, it is evident that the sea must fall to its natural level, especially as this state of things continues for more than three months. Wellsted observes that in this season, from May to October, the reefs in the northern part of the Red Sea have about 2 feet less water on them than in the remaining months of the year. This therefore appears to be the whole extent of the difference produced on the level of the Red Sea by the current, which enters it through the Strait of Bab-el-Mandeb from October to May; but the French, as already observed, found the difference between the levels of the Red and Mediterranean seas to be not less than 32 feet. It would therefore appear that the Indian Ocean itself must be about 30 feet higher than the Mediterranean, and probably also higher than the Atlantic near the Strait of Gibraltar (see below) and that the difference of level in the different parts of the ocean is much greater than is commonly supposed. This is also proved by the difference of level between the Atlantic and the Pacific on both sides of the Isthmus of Panama. According to Lloyd ('Phil. Trans.,' 1830), the mean rise and fall of the Pacific two days after full moon is 21·22 feet, and in the Caribbean Sea 1·16 feet. The water at high-water mark in the Atlantic is 13·55 feet lower than in the Pacific. The mean between the high and low water in the Pacific is 10·61 feet, and in the Atlantic 0·58. It would therefore appear that the level of the Pacific is 3·52 feet higher than that of the Caribbean Sea, as at low-water, two days after full-moon, the Pacific sinks 6·51 feet below the level of the Atlantic; but it rises at high-water 13·55 feet above it.

In this comparison of the level of the two oceans, the Caribbean Sea is placed in opposition to the Pacific: but in reasoning from existing data and our present knowledge, we must admit that the level of the Caribbean Sea is much higher than that of the Atlantic near the old Continent. The north-eastern and eastern trade-winds force a great volume of water from the North Atlantic into the Caribbean Sea, and this is increased by another large volume of water which is brought to that sea by the Guiana current, and which enters it by the straits between the islands of Martinique and Trinidad. [ATLANTIC OCEAN, in GEOG. DIV.] Such volumes of water, being arrested by the long isthmus which separates the Caribbean Sea and the Gulf of Mexico from the Pacific, must produce a considerable accumulation of water along the western shores of those seas, and raise them above the common level of the Atlantic, and this fact is confirmed by the rapid current called the Gulf stream. [ATLANTIC OCEAN, in GEOG. DIV.] Opinion varies considerably as to the difference of level between the Gulf of Mexico and the Atlantic. Poussin found the level of the Gulf at the mouth of the river Suwanee 3·75 feet higher than that of the Atlantic at the mouth of St. John's River in Florida: but when Darby, in his 'View of the United States,' estimates the difference between the Gulf near the island of Cuba and the entrance of Chesapeake Bay as at least 83 feet, we must suppose that he has formed his opinion on erroneous data. Also, we cannot accede to the opinion of Humboldt, who, in comparing some barometrical observations made at Cumana, Cartagena, and Vera Cruz, with others made at Acapulco and Callao, came to the conclusion that in these parts the Pacific was about 9·5 feet lower than the Caribbean Sea and the Gulf of Mexico. Lloyd found the reverse to be the case at the mouth of the Chagres and at Panama, as we have mentioned above.

Mathematical investigation, founded on modern exact physical research, has however led to the discovery at once of a cause of difference of level in the sea, very different from any of the causes considered above, and of an example of that difference of the most interesting and instructive character. In the 'Philosophical Transactions' for 1859, p. 779-796, is a paper by Archdeacon Pratt, 'On the Influence of the Ocean on the Plumb-line in India,' which is a sequel to two former communications on the effect of Mountain Attraction on the Plumb-line in India. In this paper the author first describes the remarkable nature of the geographical position of Hindustan, consisting in this:—that the highest mountain-ground in the world lies to the north of it, and an unbroken expanse of ocean extends from its shores down to the neighbourhood of the South Pole. Now as water is lighter than land, that is, the quantity of matter contained in a given bulk of water is less than that contained in an equal bulk of land, the attraction or attractive power of the ocean is smaller than that of the land. A given bulk of land has a greater attractive power than an equal bulk of sea. Therefore, the sea on the shores of Hindustan is more attracted by the land than by the mass of the ocean beyond. The tendency of this, therefore, is to draw up the water to a higher level on the northern shores of the peninsula than at its southern extremity at Cape Comorin. But besides this, the mountain mass of Thibet and the Himalaya [PLAINS], presents a great excess of matter on the north, above that of the land of ordinary height, and consequently has a more powerful attraction, which is added to that of the land of Hindustan generally, in drawing up the sea to a greater height at the northern extremity of the peninsula than at the southern. Accordingly, it has been found by Archdeacon Pratt that the elevation of the sea-level at Kurachee, on the north side of the Arabian Sea, is 515 feet above that at Cape Comorin, and it must be about the same at the sandheads of Calcutta, at the north end of the bay of Bengal. Now the sea is our only standard of measurement to which the form of the earth can be referred. Regarding it as the general surface of the globe, all elevations above or depressions below that surface are, as we have seen, measured from it. But these 500 or 600 feet, fortunately, are the greatest extent to which the sea-level can be affected, as there is no part of the globe where the attraction on one side, and the deficiency of attraction on the other, can be so great as in that particular portion of the world where this difference exists.

The bottom of the sea is similar to the surface of the land as to the irregular succession of elevations and depressions, and it is diversified by mountains and valleys and plains of different elevation. The summits of the submarine mountains rise above the level of the sea in the form of islands. In several parts large table-lands are found, whose surface is not at a great depth below the level of the sea: when their surface is covered with sand, they are named sand-banks; and when it consists of coral rocks, coral-banks. Near the edges of these banks the depth of the sea is generally very great. Some of the summits are barren, others are covered with vegetation, but all teem with life of one order or other. The most extensive formation of the submarine table-lands occurs in the North Atlantic. Its most north-eastern portion is formed by the Outer Bank and the Great Bank of Newfoundland. [NEWFOUNDLAND, in GEOG. DIV.] West of the Great Bank of Newfoundland are Whale Bank, Green Bank, Banquereau, and Mizen Bank. The three last-mentioned banks are situated in front of the entrance of the Gulf of St. Lawrence. Opposite the coasts of Nova Scotia are Sable Bank and Le Have Bank; and then follow, in the same south-western direction, St. George's Bank, or the banks of Nantucket, which approach the continent of North America in the vicinity of New York. From this point the banks occur at a short distance from the shores of the United States, and extend, almost without interruption, to Cape Florida and Sable Point, the most southern extremity of the peninsula of Florida. West of this peninsula is the Tortuga Bank, the continuation of which skirts the shores of the United States in the Gulf of Mexico as far west as the mouths of the Mississippi. This series of banks occupies more than 1400 miles in length; but there is always water enough on them for the largest vessels, with the exception of the Virgin Rocks on the Great Bank of Newfoundland, and the shoals of St. George's Bank. In all the other parts the least depth is not less than ten fathoms, and in general forty fathoms of water are found on them. The surface of these banks is very level. Along the northern and north-western edge, which lies opposite to the coast of America, the depth suddenly descends to 100 fathoms, and along the southern edge to 300 fathoms. The descent from the edge of the bank to the deep sea is nearly perpendicular. The banks, especially those north of 40° N. lat., are frequented by immense shoals of fish, especially cod.

The Columbian banks, under which name are comprehended all the banks which begin opposite the eastern shores of the peninsula of Florida and extend in a south-eastern direction to the Mona Passage between Haïti and Puerto Rico, are divided from the North American banks by the Florida Gulf-stream. They consist of two larger banks, called the Little and Great Bahama Bank, which occupy the north-western portion of the group, and of five smaller banks, which occur at great distances from one another in a south-eastern direction. These banks have from 15 to 20 fathoms water on their edges, but they are beset with rocks and numerous shoals, of which a few are dry at low-water: they are therefore shunned by vessels. The surface of the banks consists of coral, covered with an accumulation of shells and calcareous sand. On their eastern edges, along the Atlantic, are the Bahama Islands.

Of the smaller banks which occur in the Atlantic we shall only mention the Bank of Arguin, which lies near the western coast of North Africa, beginning at Cape Blanco (21° N. lat.), and extending to the neighbourhood of Portendik (about 18° N. lat.). It is dangerous for navigators, as there are many parts in which the water is not deep enough for large vessels, many of which have been lost on it. The Abrolhos, near the coast of Brazil, between 16° and 18° S. lat., is not extensive, but it is extremely dangerous on account of the soundings being very irregular, varying between 36 and 4 fathoms. In two successive casts of the hand-lead the soundings frequently vary from 30 to 10, and sometimes even to 4 fathoms.

There are several banks in the Indian Ocean: the most extensive are the Saya de Malha and the Bank of Nazareth. The Saya de Malha extends in length from north to south between 8° 18′ and 11° 30′, and is cut by 61° 30′ E. long. The surface is uneven, and in many places there are not more than between 6 and 10 fathoms water: it consists of corals and shells. The most southern extremity of the Nazareth bank consists of the islands called Cargados, in 16° 47′ S. lat. and near 60° E. long. From this point the bank extends in a north north-east direction to 14° S. lat. The surface is tolerably level, and the least depth of water does not fall short of 14 fathoms.

An extensive bank, called the Needle or Agulhas Bank, surrounds the southern extremity of Africa. It extends towards the west beyond the Cape of Good Hope, and towards the east beyond Cape Padrone, east of Algoa Bay. As it is not divided, like the other banks, from the continent by a tract of deeper water, it is not to be considered as a table-land, but as a submarine prolongation of the continent. Between Cape Agulhas (10° E. long.) and Cape Vaccas (22° E. long.), it extends to 37° S. lat., or to a distance exceeding 150 miles from the continent. The depth of water on this bank varies between 30 and 90 fathoms. The surface is composed of coarse sand, corals, shells, and small stones. Along its western edge it is skirted by a mud-bank, which is covered by water from 50 to 120 fathoms deep. The structure of the land is thus continued into the sea, beyond the extremities of continents, in other parts of the world also; as in the islands of Tierra del Fuego at the termination of South America. In other cases, as on the coast of Norway, there is a rapid and complete cessation of the high ground in the course of a very small distance from the shore.

There are numerous banks in the Pacific, especially south of 20° N. lat. All the larger banks are surrounded by coral reefs, on which islands of small extent often occur. [REEFS.] Near banks, the sea usually deepens to 200 and 300 fathoms, and even more.

The subject of the depth of the sea in general next claims our attention. We are best acquainted with the depth of several close seas, especially those which are much navigated. The depth of the Baltic is inconsiderable; it usually varies between 30 and 40 fathoms, and only in two or three places sinks below 100 fathoms. The North Sea is somewhat deeper in its northern part. Between the Shetland Islands and the coast of Norway the depth varies between 80 and 140 fathoms, but it gets gradually shallower towards the south. In the Straits of Dover the deepest place is only 26 fathoms. The depth of the English Channel increases as we proceed towards the west, but very slowly. East of the Eddystone it does not exceed 50 fathoms. The Irish Channel is in general deeper. Though there are some places between Wales and Ireland in which it does not exceed 40 fathoms, its general depth may be said to vary between 60 and 80 fathoms; and in the strait between the county of Antrim and that of Wigton in Scotland it attains 100 fathoms. The Mediterranean is much deeper than the Baltic and North Sea, more especially along the southern coast of Spain and about the island of Sardinia, where the depth varies between 500 and 1000 fathoms; but the deepest parts appear to be in the spaces devoid of islands to the west of Sardinia, and to the east of Malta, where the depth is about 1760 fathoms, or two miles. A shallow tract extends from Trapani in Sicily to Cape Bon in Tunis: it is called by the Italian sailors *scherchi*, and is of inconsiderable but very variable depth. That portion of the Mediterranean which lies east of this shallow tract is not so deep as the western part. The Red Sea may be compared in depth with the eastern part of the Mediterranean. [RED SEA, in GEOG. DIV.] The sea which surrounds the islands of the western gulf of the Indian Archipelago seems nowhere to sink much below 50 fathoms, and these islands, in fact, belong to the continent of Asia; but on the coast of Northern Borneo, in the Straits of Lombrok, and near the middle of the Strait of Macassa, commences, southward and eastward, a very deep sea hitherto unfathomed.

The main body of the sea has a much greater depth. In most parts of the Atlantic, where the sea has been sounded, no bottom was found with 300 fathoms. Between Europe and America the bottom seems to offer great inequalities, being furrowed by deeper tracts, which run north and south. In the North Atlantic are the greatest depths at which the bottom of the sea has been reached; the places where it has been fathomed, according to Maury, are not deeper than 25,000 feet, or about four miles and three quarters. The deepest place in this ocean is probably between the parallels of 35° and 40° N., and immediately to the southward of the Grand Banks of Newfoundland. The small general depth of this part of the Atlantic has given rise to the opinion that the sea round the North Pole is not so deep as that which surrounds the South Pole, but this opinion has no foundation. Phipps and Scoresby sounded in several places between Spitzbergen and Greenland with from 780 to 1200 fathoms, without finding a bottom; and Ellis and Ross did the same in Hudson's Bay and Baffin's Bay. In the Pacific Ocean the depth seems also to be very considerable, but few soundings have been made there.

The depth of the sea near the land varies with the nature of the shores. Where the country near the sea is elevated, and terminates in high and rocky shores, the sea is generally of considerable depth, as in the fiords of Norway. Such shores have generally good and safe harbours. But when a low plain terminates on the sea with a flat sandy bank, the sea is shallow and frequently continues to be so to a great distance from the shore. In many places such shores are inaccessible even to boats, and vessels must keep at a distance of many miles. Such shallows consist either of sand or of mud. These low shores are generally destitute of harbours, or at least they occur only at great distances, and much expense is required to maintain them in an efficient state: the harbours on rocky coasts are not subject to this inconvenience.

It is a very remarkable phenomenon, which has not yet been satisfactorily explained, that the temperature of the sea decreases as the land is approached, and it also decreases on shoals and banks; and as this decrease may be detected by the thermometer at a considerable distance from land, this instrument is now used for the purpose of ascertaining the approach to land or the presence of shoals. It must, however, be observed, that though this decrease generally takes place, it is not universal.

As late as the end of the last century it was a generally received opinion that the whole mass of sea-water, from the surface to the bottom, had the same temperature in the same latitude. But numerous observations, which have been more recently made, have shown the inaccuracy of this assumption. It has been found that the law which is constant for the earth must be inverted for the sea. The farther we descend into the interior of the earth, the higher is the temperature; but the deeper we dip into the sea, the lower is the temperature of the water. But this does not take place in the same ratio in the whole sea. Captain Ross found the temperature of the sea in Baffin's Bay, 3900 feet below the surface, + 25·52°, while the surface itself was + 33·80. Beechey, in 47° 18′ N. lat., at a depth of 5124 feet, found the water + 39·56°, and at the surface it was 46·22°. Sabine found that the water in the Caribbean Sea, at a depth of 1000 fathoms, had a temperature of 45·50°, whilst at the surface it was 83·30°. According to an observation of Franklin, the water at a depth of 650 fathoms, in 57° 44′, was 40·5°; at 450 it was 41°; and at the surface, 45°. There are a few instances in which a new increase of the temperature has been observed at a very great depth. In the following observations made by Beechey, in the Pacific, the temperature became stationary at a great depth:—

23° 28′ N. lat.		*58° 48′ N. lat.*	
Temp. at the surface	63°	Temp. at the surface	54°
At a depth of 300 ft.	62°	At a depth of 600 ft.	45°
At a depth of 900 ft.	50°	At a depth of 1200 ft.	41°·5
At a depth of 1260 ft.	47°·5	At a depth of 1962 ft.	40°·5
At a depth of 1860 ft.	47°·5	At a depth of 2652 ft.	40°·5

As a proof of the increase of the temperature of the sea at a great depth, we copy the following observations, of which the first two were made by Beechey, and the last by Prescott; the first in the Pacific, and the last two in the Atlantic Ocean:—

14° 22′ N. lat.		*55° 58′ S. lat.*	
Temp. of the air	91°	Temp. of the air	37°
Of the sea at its surface	88°	Of the sea at its surface	43°·5
At a depth of 600 ft.	57°	At a depth of 600 ft.	42°·5
At a depth of 1200 ft.	55°	At a depth of 1380 ft.	42°·5
At a depth of 1800 ft.	48°·5	At a depth of 1950 ft.	40°·5
At a depth of 2400 ft.	49°·5	At a depth of 2580 ft.	41°·5

13° 22′ N. lat.			
Temp. of the air	83°	At a depth of 540 ft.	57°
Of the sea at its surface	82°	At a depth of 660 ft.	58°
At a depth of 180 ft.	71°	At a depth of 720 ft.	58°
At a depth of 360 ft.	61°	At a depth of 1320 ft.	60°

The renewed increase at a great depth is a very difficult problem to solve: it is possible that it may be owing to submarine currents of different degrees of temperature, as some have supposed. Sir James C. Ross ascertained, by seven different experiments, that between the parallels of 55° and 58° 30′ S., there is a belt encircling the earth, where the mean temperature of the sea, that of the greatest density of its water, or + 39·5°, prevails throughout its entire depth, forming a neutral border between two great thermic basins of the ocean.

But there are facts on record which clearly show that in certain parts of the ocean there must exist some agency by which the water acquires a higher degree of temperature than might have been expected from ordinary causes. Horner, in Krusenstern's 'Travels,' observes that, in some places in the Gulf-stream, the hand-lead, when it had descended to a depth of between 480 and 600 feet, was heated to such a degree that it was impossible to take it into one's hand. A still more remarkable anomaly is presented by the temperature of the sea between Greenland and Spitzbergen. In nearly every trial, Scoresby found that this sea, at a depth of from 100 to 200 fathoms, was from 6° to 7° warmer than at the surface; and Franklin states that when he accompanied Captain Buchan in his expedition to the North Pole, the water brought from any great depth was invariably found to be warmer than that of the surface. Some persons are of opinion that the melting of the great masses of ice, by which that sea is surrounded and partly covered even in summer, may have had the effect of cooling the surface. But this is contrary to the well-established law that the colder water, being the denser, sinks to the bottom, and the warmer rises to the surface; and further, it may be asked why Ross and Parry, in navigating Davis's Strait, Baffin's Bay, and Hudson's Bay, where the masses of ice are neither less numerous nor less extensive, always found the contrary to take place.

The important subjects of the distribution of temperature in the atmosphere over the sea, and of the mutual relations of the temperature of the two elements, will be considered in the article TEMPERATURE, TERRESTRIAL, DISTRIBUTION OF.

Masses of ice surround the two poles. The cause of this has been thus generalised by Sir J. F. W. Herschel:—"Beyond the 56th parallels of latitude, the temperature of the water is lower at the surface, and rises as the thermometer descends, till the level of 39° [or the temperature of greatest density] is reached. The sea, then, even in deep water, becomes frozen at the surface in the winter months, or rather through all that portion of the year which intervenes between the beginning of September and the latter end of June; July and August being, in high latitudes, the only open months. . . . . . There can be very little doubt that, in the winter time, the surface of the ocean at both poles is entirely frozen; but at the North Pole it is probable, from many indications, that open water exists over a very large area of the central polar basin during a considerable portion of the warmer months." Some of these indications are then stated, but a fuller view of them will be found in Sir John Richardson's 'Polar Regions,' pp. 222-231.

It was formerly conjectured that the mass of ice inclosing the North Pole extended to the vicinity of 81° N. lat., because all navigators who had attained that latitude agreed in stating that the ice there rose to a great height, and stood firm like a wall. This general opinion gave rise to the attempt of Captain Parry to reach the pole by travelling on this ice, which was supposed to be immovable. But Parry was soon aware that he was travelling on ice which was in continuous motion, being carried by a current towards the south and south-west, and this circumstance occasioned the failure of the undertaking. When he had advanced, according to his calculation, several miles to the northward in twenty-four hours, he found, on observing the altitude of the sun, that the motion of the ice had carried him as far southward, and that for several days he had advanced very little nearer to his object. He was obliged to abandon the attempt, after having reached 82° 40¼′ N. lat. Thus we have learned that the exterior parts of the great mass of ice supposed to inclose the poles consists of moving masses, which lie close together, and are only occasionally divided from one another by narrow straits. The pieces of ice which detach themselves from this great accumulation and enter the open sea are called *heavy drift-ice*. The larger pieces of ice of this description are a mile in length and breadth, and upwards of 30 feet in thickness; but others are of less dimensions. The farther they advance southward, the more their dimensions are reduced by the action of the sun and of the water. But there are two other descriptions of ice-masses in the sea, which appear to have a different origin—the ice-fields and the icebergs. The term *ice-field* is applied to sheets of ice so extensive that their limits cannot be discerned from the mast-head. They often occur of the diameter of 20 or 30 miles, and, when they are very closely united, they sometimes extend to the length of 50 or 100 miles. Their average thickness may be from 10 to 15 feet, and their surface is mostly level, except where *hummocks* or low ice-hills occur, and then the thickness is often 40 and even 50 feet. These hummocks are produced by two fields coming into contact, when their broken edges are raised by the violent concussion, and thrown upon the fields themselves. These hummocks, therefore, are usually situated near the edges of the field. In some fields the hummocks form ridges or chains; in others they consist of isolated peaks. The smaller fields, or those whose extent can be seen from the mast-head, are called *floes*. The surface of these masses of ice, before July, is always covered with a bed of snow from a foot to a fathom in depth; this snow dissolves in the end of summer, and forms extensive pools and lakes of fresh water. The great extent and the level surface of the fields show that they cannot be portions of the ice over which Parry travelled. It is therefore supposed that they are generated in the sea which lies between Greenland and Spitzbergen, and which, though navigable during the summer, is covered with a continuous sheet of ice in the colder season. The fields appear to be the parts of this great sheet, formed by its breaking up at the approach of summer. When, on the further advance of the season, the field-ice and floes of the general surface break, the ice becomes heaped together in sheets confusedly piled on each other, into what is called *pack-ice*, or an *ice-pack*. The pellicle of ice formed over great areas of the polar seas, as the immediate effect of a general depression of temperature below the freezing-point of sea-water, is called *pancake-ice*. It is, in fact, the beginning of the production of ice in the ocean; and the possibility of its existence, as well as that of all continuous masses of ice, depends on the property of regelation, to which Faraday has recently called attention [ICE; WATER], and which Tyndall has applied with so much success to the elucidation of the phenomena of glaciers, the parents of *icebergs*, to which we must now proceed. These are immense masses of ice rising to a great height above the level of the sea; some of them attain a height of 100 feet above the surface of the sea, and a few have been found which seem to be more than twice that height. Their base near the sea-level is not extensive, the larger masses generally being not more than 4000 feet in circumference, though Middleton states that he saw one which was from three to four miles in circuit. The most common form of the iceberg is for one side to rise perpendicularly to the very summit, the opposite side being very low, while the intermediate surface forms a gradual slope. Some have regular flat surfaces, but frequently they present a great variety in form and appearance. Some of them resemble palaces, or churches, or old castles, with spires, towers, windows, and arched gateways; while others resemble pyramids and obelisks, and others are like ships, trees, animals, and human beings. When a number of them are near one another, which frequently happens, they present the appearance of a mountainous country. When seen from a short distance, they look like huge hills of marble; and when the sun shines on them, they glitter like silver. Sometimes earth, gravel, and sand may be observed in them. Their prevailing colour in the fresh fracture is greenish-gray, approaching to emerald-green. This colour resembles that of the glaciers of Switzerland [GLACIERS, in NAT. HIST. DIV.], and the icebergs are masses broken off from glaciers, or from barrier lines of ice-cliff. They are rarely met with in the sea between Greenland and Spitzbergen, because in these parts only a few glaciers approach near the water's edge. But on both sides of Davis's Strait and Baffin's Bay, and also on the eastern shores of Greenland as far north as 70° N. lat., glaciers cover the land, and in many places advance to the shores of the sea. In some places they terminate in a precipitous edge on the coast. It is only in the sea which surrounds these coasts that the icebergs are numerous. They seem to owe their origin to the circumstance of glaciers being in a continual state of progress. The glaciers of Greenland, which are situated on the margin of the sea, protrude their exterior parts over the ocean, and in summer, when the ice becomes brittle, the force of cohesion is overcome by the weight of the prodigious masses that overhang the sea, and they are detached from the glacier with a dreadful crash. Thus an iceberg is formed. These icebergs, as it seems, are most common along the eastern shores of Greenland, and at the distance of 15 to 20 miles from the coast, where they occur by hundreds and thousands, forming a sort of barrier outside the drift-ice which is near the shore, and preventing its removal by an off-shore wind. Captain Graah states that this barrier of icebergs renders it impossible for vessels to approach these shores.

These masses of ice render navigation very dangerous; and the ice-fields especially have caused the loss of many whaling-vessels. These extensive masses are frequently put into a rotatory movement by a cause which has never been discovered. When thus whirled about, their outer edges acquire a velocity of several miles per hour. A field thus in motion, coming in contact with another at rest, or with one that has a contrary direction of movement, produces a dreadful shock. The strongest ship is a mere atom between two such masses of matter in motion, and many vessels have thus been destroyed. The ice-fields are particularly dangerous in foggy weather, as their motions cannot then be distinctly observed. Icebergs are much less dangerous, partly on account of the small space which they occupy when compared with ice-fields, and partly because they are easily distinguished at a distance in the night by their natural brightness, and in foggy weather by a peculiar blackness of the atmosphere. As, however, they occur far from land and often in unexpected situations, sailors when crossing the Atlantic between 50° and 60° N. lat., or even farther to the south, must always be on the watch for them in the night time. Occasionally the whale-fishers derive some advantage from them. As they sink deep into the sea, they are very little affected by the wind, and they furnish secure mooring to a ship in strong adverse winds, or when it is required for other purposes. But mooring to lofty icebergs is attended with considerable danger. Being sometimes very nicely balanced, they are apt to lose their equilibrium; and vessels have often been staved and sometimes wrecked by the fall of their icy mooring, while boats have been overwhelmed even at a considerable distance by the swell occasioned by such a catastrophe. Water is sometimes procured by whaling-vessels from the deep pools of water that are formed in the summer season on the depressions in icebergs, or from the streams which run down their sides.

On approaching a field or any compact aggregation of ice, the *ice-blink* is seen whenever the horizon is tolerably free from clouds, and sometimes even under a thick sky. It consists of a stratum of lucid whiteness, which appears over the ice in that part of the atmosphere which joins the horizon. A clear sky presents a beautiful and perfect map of the ice, 20 or 30 miles beyond the limit of direct vision, but less distant in proportion as the atmosphere is more dense and obscure. Each kind of ice has a different blink. Field-ice has the most lucid blink, accompanied with a tinge of yellow; that of packed ice is more purely white; and ice newly formed upon the sea has a grayish hue.

According to the experiments of Scoresby, the specific gravity of the ice, when compared with that of sea-water occurring in the Greenland Sea, at the temperature of 35° was ascertained to be from 0·894 to 0·900. That part of the ice, therefore, which is above the surface appears to be, to that below the surface, in the proportion of 1 to between 8 and 9. For every solid foot of ice which is seen in a mass floating in the sea, there must be 8 or 9 feet below. Hence it sometimes happens that large icebergs, when they are carried into shallow water, take ground, and remain stationary for one or two years, until so much of their volume has been wasted by the action of the sun and of the atmosphere, that they begin to float again.

It excited some surprise when it was discovered that the ice floating about in the sea consisted of fresh water. It is true that it generally contains a very small portion of salt, but it is probable that this small portion of salt is derived from the salt water contained in the pores of the ice. If, says Scoresby, in confirmation of this opinion, the newest and most porous ice be removed into the air, allowed to drain for some time in a temperature of 32° and upwards, and then be washed in fresh water, it will be found to be nearly quite free from salt, and the water produced from it may be drunk. According to the Russian explorer, Baron Wrangell, whenever the surface of the ice on the north coast of Siberia is clear of snow, the salt may be found deposited in crystals; and in the neighbourhood of the *polynias*, or interior open seas of the Arctic regions already mentioned, the layer of salt is often of considerable thickness. All this is in conformity with the fact, first definitely ascertained by Dr. Faraday, that in the process of freezing the foreign bodies contained in water are separated from it; agreeably to a principle which appears to be manifested in the crystallisation of most if not all fluids, of the separation of heterogeneous matter. On account of the salt contained in it, sea-water does not, like pure water, freeze at the temperature of 32°, but in the Greenland Sea, where its specific gravity is 1·0263, it begins only to freeze at 28½°.

There is not any portion of the surface of the sea which is not subjected to some kind of motion, and this circumstance must tend greatly to preserve its purity. The water in some parts of the sea is always propelled in the same direction by the currents. [ATLANTIC OCEAN; PACIFIC OCEAN, in GEOG. DIV.] Nearly the whole sea is four times in the day subject to a change in its level by the movements of the tides. The motion produced by the winds, and known by the name of waves, is much less regular. Each wave presents a gently ascending surface to the windward, and a perpendicular descent leeward. The elevation of the waves varies according to the strength of the wind. A rather heavy gale raises them from six to eight feet above the common sea-level; but in very strong gales they attain an elevation of thirty feet. This motion of the surface of the sea is not perceptible to a great depth. In the strongest gales it is supposed not to extend beyond 72 feet below the surface, and at a depth of 90 feet the sea is perfectly still. The form and even the size of the waves vary according to the depth and the extent of the sea. In shallow water, where the lower part of the waves approaches the bottom, and meets with resistance, the waves are abrupt and irregular, and this is also the case in confined seas; whilst on the open ocean they are wide and long, and rise and fall with great regularity. When the waves run to a low shore, the slope of the ground breaks their force, and they terminate in a tranquil manner; but when they are impelled against an elevated rocky coast, being repelled by the rock, they produce what is called a *surf*. This violent rising of the sea on a rocky coast sometimes attains an elevation of 100 feet above the sea-level. The surf is always dangerous to pass, except in boats of a peculiar construction. The waves do not subside simultaneously with the wind. The momentum of the water preserves the sea in its agitated state for many hours. The air being little agitated, or not at all, is unable to depress the undulations of the sea, and therefore the waves during a calm after a gale rise higher, and their most elevated part forms a more acute angle than during the gale. Such a state of the sea is called a *hollow sea*. [WAVE.]

The term *Ocean* (a Greek word, Oceanus, Ὠκέανος) is applied in a general and somewhat indefinite manner to distinguish the greater areas of sea. The word first occurs in Homer, who uses it to designate the river or stream which, according to his ideas, surrounded the surface of the earth like a circle. The Greek geographers, however, knew that the ocean was a wide expanse of water, which surrounded the land, and the term ocean was used by them in this sense. They supposed that it penetrated deep into the mass of the continent by four great bays or seas: these were, on the south the Arabian Sea and the Persian Gulf; on the west the Mediterranean; and on the north an imaginary strait which connected the Northern Ocean with the Caspian Sea. (Strabo, p. 121; Pomp. Mela, i. 1.) [GEOGRAPHY.]

The actual surface of the globe may be reckoned at about 197,000,000 of square British statute miles; of which 145,000,000 are covered by the waters of the ocean—now using this term in its widest and most emphatic sense, as meaning the entire collection of seas—while the area of the land is about 52,000,000 of miles; the proportion of land to sea being thus as about 1 to 3, the land occupying one-fourth, and the sea three-fourths of the entire surface of our planet. The latter, however, is so unequally distributed that there is three times more land in the northern than in the southern hemisphere. The torrid zone is principally occupied by sea, and only one-twenty-seventh part of the land on one side of the earth has land opposite to it on the other. Sir John Herschel has recorded, that "one result of maritime discovery on the great scale, is, so to speak, *massive* enough to call for mention as an astronomical feature" of our planet. "When the continents and seas are laid down on a globe (and since the discovery of Australia, and the recent addition to our Antarctic knowledge of Victoria Land by Sir J. C. Ross, we are sure that no very extensive tracts of land remain unknown) we find that it is possible so to divide the globe into two hemispheres, that one shall contain *nearly all the land*; the other being almost entirely sea. It is a fact, not a little interesting to Englishmen, and, combined with our insular station in that great highway of nations, the Atlantic, not a little explanatory of our commercial eminence, that London occupies nearly the centre of the terrestrial hemisphere." He adds that "more exactly Falmouth," the most westerly port of Great Britain, occupies this centre. "The central point of the hemisphere which contains the maximum of land," he continues, "falls very nearly indeed upon this port. The land in the opposite hemisphere, with the exception of the tapering extremity of South America and the slender peninsula of Malacca, is wholly insular, and were it not for New Holland would be quite insignificant in amount." 'Outlines of Astronomy,' par. (284). Another illustrative view of the distribution of land and water has been given by Professor Ansted. In the space between the Equator and the Antarctic Circle (consisting of the southern half of the Torrid Zone and the whole of the South Temperate Zone) which occupies 90,000,000 of square miles, nealy 77,000,000 (almost seven-eighths of this space) are water, while in the North Temperate Zone the quantity of land is nearly equal to that of water. As the great depressions on the solid surface, occupied by the principal part of the water on the globe, are connected together by comparatively narrow passages, and are therefore really united, forming one wide and continuous expanse of sea, the emphatic application of the term ocean, in the singular, is as obviously correct in modern science, as it was in its original use by the Greeks. But notwithstanding this unity, the different parts of the ocean are known by distinct names, the most important being the Pacific, the Atlantic, Indian, Arctic, and Antarctic oceans. There are also some internal seas of considerable extent, as the Mediterranean, the Baltic, and others, which are almost entirely inclosed by land, and, like the ocean, are filled with salt-water; besides the isolated Caspian and Sea of Aral, and also the great gulfs and penetrating bays of North America, together with others, better known, but far less extensive, in Europe.

In considering the *Physical Changes of the Ocean*, we find that the relations of sea and land in respect of area, height and depth, interchange of moisture, aërial currents, and many other circumstances which influence mechanical, chemical, and vital phenomena on our globe, are so important, and, within the compass of the few hundreds or thousands of years which belong to history or tradition, appear to have suffered so little change, that nothing short of the complete proof furnished by geology ought to satisfy our minds that every one of the conditions which make up the now harmonious mutual dependence of land and sea is variable, that the present aspect of the globe is but one term of a long series of successive transformations, the law of which—the great problem of geology—is perhaps not beyond the reach of observation and induction. But as we proceed in this inquiry, we learn the important lesson that the present history of any of the great elements of terrestrial nature is imperfect, cannot in fact be ascertained, without the light derived from its past history, of which it is the continuous production. The sciences of Geology and Physical Geography are thus found to be parts of each other, alternately, according to the aspect in which they are viewed. Nearly all aqueous geology, or the knowledge of the deposition of the fossiliferous strata, consists in investigating the physical changes of the sea during past ages of the earth's history, of which the changes it is now undergoing are the ever-proceeding completion.

Are the relative areas of sea and land constant? To this geology replies, that what is now land was formerly the sea; that in some of the parts which are now covered by water land anciently existed, so as to pour down rivers, conveying sediments of different sorts through valleys and plains clothed with various vegetation. The land which we behold is the bed of the ancient sea; or, to speak more precisely, it is composed of the dried indurated sediments and the cooled volcanic products which, during long intervals of time, were accumulated beneath the ocean. Whether, during the process by which the ancient sea-bed was raised to constitute our now dry land, a proportionate area of what was formerly land was depressed to constitute the modern sea-bed, is an unsettled question; but it is clearly proved that if any proportion of areas between sea and land is a necessary condition of our globe, all the parts of these areas are displaceable and have been displaced.

Is the relative level of the land and sea constant? We cannot affirm it. We cannot deny the existence of causes which may change generally and continually this relation, any more than the operation of agencies which locally and at intervals are known to derange it. If there be a general change of temperature in the earth itself, or communicated from the planetary spaces around it, or occasioned by any condition affecting the radiation of heat in the atmosphere above it; the unequal influence of this change on the unequally expanding and contracting liquid and solid masses will necessarily occasion variations in the relative level of sea and land. Now, geology appears to have established many facts regarding the fossil organic remains of plants and animals, which admit of no clear general explanation except by supposing extensive, perhaps general changes of climate. There is nothing positively known which forbids the belief that such changes may be still really, however slowly, in progress; there is abundant proof of innumerable local derangements of the level of land and sea in comparatively modern geological, historical, and even very recent periods, and a slow upward movement of land is actually traceable and measurable on the coast of Sweden and Norway.

A change of a few degrees of temperature, a change of the relative height of the land, a change even in the polar distance of the masses of land, would materially affect many secondary phenomena. The atmosphere would be affected in regard to its moisture, translucency, rate of diminishing temperature, prevalent winds, and quantity of rain. Its power of sustaining particular organic structures both on the land and in the sea would be altered; and thus we see in the variable nature of the relations which unite the land and the sea, elements of continual change in the mechanical, chemical, and vital phenomena of the globe.

The ocean is continually receiving the spoils of the land, by means of the rivers and the action of the waves on the sea-coast; and from that cause, theoretically, would be constantly decreasing in depth, and as the quantity of water is always the same, its superficial extent would increase and its level consequently rise. There are, however, counteracting causes to check this tendency; the secular elevation, or gradual elevation during the course of ages, over extensive tracts in many parts of the world, is one of the most important of these. Volcanos, coral-islands, as well as the coral structures called barrier-reefs, show that great changes of level are constantly taking place in the bed of the ocean itself. In addition to these, it has been conclusively evinced by Mr. Darwin, that symmetrical bands in which the bed of the sea is subsiding below and being elevated above its level at a given time, extend alternately over an area (in the Pacific and South Atlantic oceans) equal to half that of the entire globe. From all these facts it may be concluded that the balance is always maintained between the land and the sea, although the distribution of each, respectively, may vary in the lapse of time. But independently of all these counteractions, so immense is the proportion which the magnitude of our planet bears to the power of the agencies which are at work upon its surface, that, as has been shown by Mr. Alfred Tylor, in a communication to the Geological Society, the action of the sea on the shores, and of the rivers upon the land,—if the matter they all wear from the land, and carry down in the form of sand and mud, together with that, probably still greater in quantity, which they carry down in chemical solution, to be decomposed in the sea, and in part precipitated on its bed,—were uniformly distributed over the entire bed of the ocean, the level of the water would not be raised more than three inches in ten thousand years, which is an amount absolutely insignificant, and would not be measurable for many times that period, nor otherwise sensible to man for many more.

What is the actual mean level of the sea? By the researches of Captain Denham at Liverpool, by the careful measurements taken by Mr. Bunt in the Bristol Channel, under the direction of Professor Whewell, and by some experiments of Sir H. de la Beche on the coasts of Pembrokeshire, it appears that the mean of high and low water is nearly at the same point, whether spring or neap tides be measured. This mean or half-tide level, which is often nearly coincident with the middle point of time between high and low water, can be ascertained by a few observations at any age of the moon in quiet weather, and should always be employed as the datum or zero line in recording elevations of mountains, heights of canals, summits, railway stations, &c. Above all it should be taken for the term of comparison whenever it is wished to determine the relative elevation of different parts of the open sea, though there may be cases when landlocked waters and tide rivers may require the use of another line of reference. The horizontal line which bounds the land and sea, the outline of the coast, is variable; it is annually displaced by the wasting of some tracts and the augmentation of others. Since the Roman sway in Britain, a large portion of the rich marsh-lands of Norfolk, Cambridge, Huntingdon, &c., have been recovered from the retiring sea; but in the same period the east coast of Yorkshire has lost many square miles of territory, and is still losing at a fearful rate. (Sir C. Lyell has collected abundant examples in his 'Principles of Geology.') This unequal action depends partly on the *slope* with which the land and sea meet; partly on the nature of the materials comprising the coast, partly on the *set* of the tides and currents.

The modern ocean is the theatre of many operations similar in kind to those by which the materials of dry land were formerly accumulated beneath ancient seas. The bed of the Adriatic was found by Donati to resemble the surfaces of sub-Apennine tertiary strata; the shallow soundings of the English Channel and German Ocean show, in the distribution of shells and fish-teeth, analogies with several of the secondary rocks; while in the coral reefs of warm latitudes, on sandy or pebbly shores generally, and at the mouths of great rivers, we see the production of limestone, sandstone, and clay deposits, very similar to those which abound in the stratified masses of land. Whoever will compare with attention the ripple or current mark on the sea-shore with the corresponding undulations on slates and sandstones of every geological age, will be convinced of the identity of the causes of these impressions; and when he beholds such surfaces in rocks covered by other deposits thousands of feet thick, will not hesitate to admit in such cases that great depressions happened along the margin of the ancient sea during the formation of these strata, followed by still greater elevations at a later period.

The distribution of life in the modern ocean is one of the circumstances most important to know. Until very recently it has been supposed that below some moderate depth (moderate at least as compared with the thicknesses of the strata) life ceases in the ocean from deficient light and air, and augmented pressure.

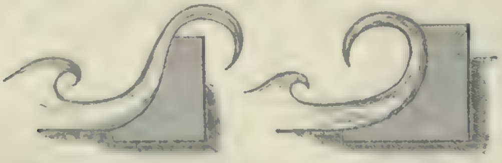
Within these few years, however, reason has been seen to modify these conclusions; and in the course of the past year (1860) the researches of Dr. G. C. Wallich, on the bed of the North Atlantic, have shown that animal life, in various forms of foraminifera and radiata, if not of higher groups, exists at vast depths. It ought, indeed, to have been seen long ago, that the uniform distribution of pressure effected by the water, would necessarily preclude the destruction which it was reasonable to infer that the partial accumulation of pressure would have caused.

The proportion which exists between the sea and land has contributed to maintain the productive powers of the earth. If that proportion were materially changed, its productive powers would be changed also. The sea, by means of the vapours continually rising from its surface, supplies the atmosphere with sufficient moisture for the support of organic life. Countries which do not partake of the benefits derived from this source, and which are not refreshed by rain or dew, are uninhabitable and destitute of all kinds of vegetation. Those parts of the earth which are farthest from the sea are much less fertile and populous than those which, owing to their greater vicinity to it, receive a larger supply of moisture from this great source. The sea contributes also considerably to the advancement of civilisation. At the first view it seems to constitute an insuperable obstacle to the communication between nations who inhabit countries widely apart from one another; but the ingenuity of men has converted the ocean into the most frequented high road on the globe. The easy communication which is thus established between nations at great distances from one another, has perhaps more than any other circumstance contributed to improve the condition of the human race. It is at least certain, that all those nations which have acquired any considerable degree of civilisation inhabit countries either contiguous to the sea or at no great distance from it.

On the subjects of this article, four works may be particularised, which, of course among many others, may be consulted with advantage: Sir John F. W. Herschel's 'Physical Geography;' Admiral Smyth's 'Mediterranean;' Sir John Richardson's 'Polar Regions;' and 'The Physical Geography of the Sea, and its Meteorology,' by Captain Maury, the American hydrographer. The last is an immense repository of facts, relating chiefly, however, to the Atlantic and its marine dependencies; and many views entertained by the author are not wholly accepted by British hydrographers and meteorologists.

SEA DEFENCES. When the tidal action, or littoral currents attack a sea-shore, it becomes necessary to protect the latter from the gradual abrasion thus produced. The mode in which the defences thus required are constructed, must depend not only on the peculiar form of destructive action to be guarded against, but also on the nature of the materials at hand; the various conditions to be observed may, therefore, be the most conveniently noticed in the course of the description of some of the most important works of the kind actually executed.

On rocky shores of the granitic and crystalline formations, the sea acts principally by its direct impact, or by the tidal currents, although, no doubt, the effect of the constant humidity, and of the splashing of the waves, must produce a destructive action on the constituent parts of the rocks. In these cases, and especially when deep water comes close in-shore, the most economical, and in all cases the most efficient sea defence consists of a solid masonry wall, built of the largest and hardest stones which can be obtained, and finished with a curvilinear batter of about 1 in 40 from the sea. Colonel Emy, and the French, Spanish, and German engineers sometimes make the upper parts of their curvilinear defence walls continue beyond the axis of the curve, so that at the top the curve again comes towards the sea; and they adopt this construction because they believe that, in consequence of the projection of the top, the crown of the wave striking and running up the face of the wall would be thrown outwards, instead of breaking over the wall. It is to be suspected, however, that the repercussion produced by the wave falling upon the toe of the wall is even more injurious than the effect of the water falling at the back or inside; and the best hydraulic engineers at the present day are in the habit of erecting their sea-walls with continuous batters in the same direction, and of protecting their in-shore faces by good paving on the top of the backing, and by good drainage. It would be impossible to attach too much importance to the necessity for providing against the effect of any sudden interference with the translation of a deep sea wave, especially when it has been driven for a short distance over an inclined fore shore, and has been exposed to the action of winds or currents able to increase the velocity of its motion. In some cases, the velocity has even been observed to attain as much as 70 feet per second; and from observations made at Cherbourg and Algiers, it would seem that the power of waves to communicate horizontal motion sometimes attains as much as 291 lbs. per foot superficial. The spray has at times been dashed over the Bell Rock, a height of 117 feet; and Lord Adair states, that he has measured on the coast of Ireland, rolling breakers of 150 feet in height. The quantity of water a wave of this description might carry over the crown of a wall would be enormous; and though there may be few positions wherein they occur, even smaller waves are capable of producing effects of a very serious nature, if the water they furnish were not prevented from washing away the backing of the structure on which they might break. On the shores actually exposed to the shock of such waves as those described by Lord Adair, it would be almost impossible for human skill to contend with the forces of nature; but fortunately, these waves are only to be met with on what are known as iron-bound coasts, where the character of the rocks is such as to enable them to resist the action of the sea.



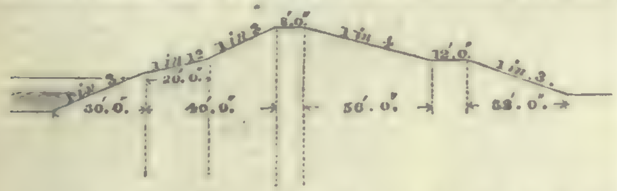
It may be gathered from the preceding remarks, that if it be thus necessary to guard against the tendency of breaking waves to produce lateral displacement, and to remove the backing of a defence wall, it must be equally important to guard against the tendency to undermine the footings on the seaward face produced by the receding wave, or the *undertow* as it is technically called. This object is usually effected in the more moveable strata, by constructing an apron, or in fact, a species of flat wall, presenting the same inclination as the natural line of the fore shore; and built with every precaution to ensure the stability of its face, by the introduction of longitudinal and of transverse ties, and by protecting the edges by continuous piling. At the Plymouth breakwater the sea slope was paved with large blocks of marble, or of granite, dovetailed and cramped together at an enormous cost; at Cherbourg, the sea slope was protected by huge blocks of rubble masonry set in Portland cement; and on the Dutch coast, where the angle of inclination of the shore is extremely flat, the apron walls of sea defences are often made of brickwork set with trass mortar in wooden frames. The choice of the system to be adopted in any particular case must depend on the maximum violence of the waves there observed; but it may be worth while here to mention that in exposed situations on the shores of the ocean, blocks of nearly 500 cubic feet, of a material possessing a specific gravity of 2·2, are susceptible of being displaced by the force of the waves.

These remarks with respect to defence-walls on the shores composed of resisting rocks apply equally, or rather *à fortiori*, to the defences required for formations of a softer nature. The action of the sea upon them is, however, of a rather more complicated nature than that which takes place on granitic, or crystalline shores; for it will in many cases be found that at the feet of limestone, or clay cliffs, there are large deposits of shingle composed of the detritus of harder rocks, carried forward by the force of the currents, and of the tides, according to peculiar laws. If this shingle should only advance slowly it may tend to protect the surface of the shore, by forming as it were a matlass on which the waves might break without affecting the subjacent rocks; but if, on the other hand, the shingle should have any tendency to lateral displacement, it will materially assist the abrading action of the littoral currents by the friction it exercises at the base of the cliffs. The outlines of a limestone, or of a clay, shore often bear traces of this action; and they exhibit cliffs which are nearly vertical in their upper portions, but hollowed out about the zone of tidal action; at their feet there is usually a shingly beach, in which the stones have been abandoned by the receding waves according to the specific gravities of the stones themselves, or, in other words, the largest pebbles are always at the top of the beach. The defence of shores of this description may either be effected by walls with aprons, as before-mentioned, or by the construction of stonework, or of timber, groynes, placed at right angles to the advance of the shingle, in order to fix the latter. Groynes are in fact dwarf-walls, projecting more or less above the face of the beach, and continued to about the line of low water; and they act by retaining the advancing shingle in the re-entrant angle, until it has accumulated to such an extent as to be carried round the point, or over the top of the groyne. In great storms the groynes are often laid bare, and there is danger of their being then undermined; and, indeed, the actions to which they are exposed are so violent, that it may fairly be laid down as a rule that it is preferable to form them of cheap, temporary materials, than to form them in a permanent manner.

The consolidation of shores of soft alluvial formations may be effected in various manners, according to their outlines under the action of the currents. If the natural inclination should happen to form a very small angle with the horizon from the line of the low water, it would generally be desirable to crown the top of the slope by a vertical wall, of either masonry or of timber. In Holland the dykes are executed of earth work, sometimes with rather an abrupt talus towards the sea, which talus is protected by stone pitching; at others the slope is made with a much flatter angle, and two or three parallel rows of piles, standing up above the face of the slope, are inserted for the purpose of breaking the force of the waves; and at others, the face of the earthwork is protected by a species of wall composed of bundles of reeds, fascines, &c. The hearts of these embankments are formed with reeds and fascines, and especial care is taken to attach them firmly to the subsoil, as well as to secure an efficient system of back drainage. Many instances occur in which the banks of the more protected polders of Holland and Flanders are constructed in the same manner as coffer-dams, that is to say, by means of puddle banks rammed in between sheeting enclosures; and near Havre, in the bay of the Seine, the fore-shore is defended by a regular timber stockade formed of whole timber piles, whales and back ties, and of horizontal planking spiked to the outer faces of the piles; earthwork is carefully rammed at the back of these planks.

It is necessary to guard against the destructive chemical action of the sea-water upon the materials employed for any of these systems of shore defences; and when the soft limestones, or wood, are employed, to take seriously into account the ravages which may be committed by the various descriptions of boring conchiferæ, and worms. The pholas, solen, and lithodomus attack the calcareous stones; the teredo navalis and the lymexylon attack wood, in the temperate latitudes of Europe; in tropical climates there are other species of animals of even a more destructive nature still, which feed upon, or burrow in, both those classes of materials.

It may be as well to add, that in the cases wherein the Dutch engineers content themselves with sand dykes, faced with reeds, the minimum dimensions they employ are about as indicated in the sketch;



but in very many instances they make the sea-slope with an inclination of even 1 in 20, when the natural profile of the foreshore presents a very flat incline. With the very light materials dealt with in these cases it is indeed preferable to conduct the waves up a long easy slope on which they can exhaust their power, than to attempt to oppose an abrupt resistance to their shock. When stiff clay is the material used for the banks, and no protection is given, the slope is made equal to 1 in 10; when light sand is used, the slope is made 1 in 20, whatever may be the profile of the foreshore. At the mouth of the Thames and Medway the marshes are defended by slopes of 1 in 4, protected by a concrete bed covered by stone pitching, laid between rows of stakes driven firmly into the banks, and between rows of piles at the top and bottom. (See Minard, 'Ouvrages Hydrauliques des Ports de Mer, &c.')

SEA LIGHTS. [Trinity House.]

SEA SALT. [Sodium. *Chloride of Sodium.*]

SEA WATER. [Sodium.]

SEAL, an intaglio or relief impression on wax, clay, paper, or other substance made from a die or *matrix* of metal or other material, by which the impression is produced, derived from the French *sceau*, *scelle*, or *saiel*, first used in the 11th century; the Latin *sigillum*. Seals, called *khatem*, were in use at the earliest period in Egypt, the matrix generally of square shape revolving in a large ring, or attached to a chain; those of kings and high dignitaries of gold, silver, or precious stones, while the inferior people used scarabæi, *kheperu* of porcelain, or vitrified soapstone with the subject engraved in intaglio, set in rings as signets. Impressions or seals from these were made in fine Nile mud or clay, and attached by slips of papyri, linen or cord, to documents [Papyrus], while at a later period coloured wax and even lead were employed. [Mummy.] The engravings were deities, royal and other names, emblems and mottoes. Impressions of seals with the names of Sheshank, Nafaarut, Amasis, and other monarchs, exist in the British Museum. Seals were extensively used by the Egyptians: tombs were sealed with mortar, letters and other documents being rolled in a cylindrical form and sealed outside, and the sacred victims, bread, and other objects, were also sealed. The ancient Hebrews appear to have worn their signet-rings or *khatam* as rings or bracelets (Gen. xxxviii. 18); they were made of engraved onyx (Exod. xxxix. 6), and documents were sealed with them. Ahab with his own hand; Ahasuerus by his chancellor Haman, and Darius himself, impressed the seals of their decrees. When Alexander the Great conquered Persia he used the seal of Darius for his rescripts in that country.

The signets of the Assyrians consist of cones of chalcedony and other stones pierced and engraved, which were set in rings or suspended to chains or cords: the principal device is a rampant lion pierced by a king, deities and other devices; they also used cylinders of green felspar and onyx, with kings, animals, and other objects, and inscriptions containing the names and titles of kings, those of Sennacherib being found at Kouyunjik (Layard, 'Nineveh and Babylon,' p. 154). Impressions from similar signets in fine clay were discovered in the ruins of Kouyunjik, and those of witnesses or contracting parties are found on clay documents. The use of cylinders, for this purpose, of hematite, steatite, chalcedony, and onyx was prevalent amongst the Babylonians, such being engraved with deities, zodiacal signs, and inscriptions, and continued under the Persians, who used by preference red cornelian, that of Darius or his viceroy having been found in Egypt. The Phenicians appear to have employed scarabæi of cornelian or sardonyx for the same purpose, and the Etruscan signets were scarabæi of the same or onyx, with devices of native deities, or the principal heroic and mythic personages of Greece, with Etruscan legends.

At the earliest epoch the Greeks used impressions of worm-eaten pieces of wood. The use of signets and seals among the Greeks appears to be as old as the 6th century B.C., the earliest example being the celebrated emerald ring engraved by Theodorus for Polycrates, tyrant of Samos. Such signets were called *sphragides*, *semata*, *semcia*, or *semanteres*, and were worn on the fourth finger of the left hand. Those of metal only were called *apsephoi*, the stone itself being *psephos*, and the chaton *sphendone*, *ecmageion*, *aposphragisma*, *ectyposna*. The impression of the seal was made on a fine clay, the *ge semantris* or sealing earth, not wax. Seals were placed on doors, and on things in the house to prevent the pilfering of slaves. The seal itself was protected by a shell or scale.

The use of signets amongst the Romans appears to have been introduced by the Etruscans, whose *gemmati annuli*, or rings with stones, were subsequently used by the Romans as old as Tarquin the elder. Senators sent as ambassadors had a gold official signet given them by the State, but used an iron ring in private: gold rings or signets were limited to the senators and knights, and the *jus annuli aurei*, or rights of the gold ring, had a certain legal status under the Empire. But their use was extended by Tiberius to freedmen, by Severus Alexander and Aurelian to the troops, and under Justinian it had entirely disappeared. The signet of the Emperor was a state seal, generally engraved with his own portrait or favourite device. The chaton, or place which held the stone, was called *pala*. The various gems were engraved by excellent artists, who sometimes placed their names, or the name or initials of the possessor, on the stone; but glass seals, called by the Greeks *sphragides hyalinai*, and *vitreæ gemmæ* by the Romans, were used by the poorer classes. These came first into use about 416 B.C. The impressions were made in Lemnian and sealing clay, *cretula*, *sigillaris creta*, stucco *maltha*, or still more frequently wax. The Romans sealed bags of money, granaries, doors of female apartments, and other objects, but principally writings or letters; the papyrus or tablet was tied up with a cord and the seal, *signum*, placed on it; wills particularly required seals, and under Nero the law ordered them to be pierced at the margin with a cord, which thrice passed round them, and the seal was then applied, and the prætor required the seals of the seven witnesses to validate a will. The devices of the seals of the emperors appear to have varied, and no particular symbol was used for the state seal. Julius Cæsar used Venus, Augustus a sphinx, which he changed for the head of Alexander the Great, which continued till Nero; the following emperors used various symbols. Private individuals used indifferently all sorts of devices During the Empire leaden seals were used for private purposes, and after the age of Constantine, flat circular metallic seals called *bullæ*, made of gold, silver, and lead, attached by silken or woollen bands to the documents, came into use.

The Byzantine commence with Valentinian and Valens, A.D. 364, and have on one side the figure of the Emperor, on the other that of Christ or the Virgin; dignitaries and private persons of the epoch also employed leaden seals, with Christ or the Virgin, or only their own names and titles. The devices of the seals of the Christians at this epoch were fishes, fishermen, lambs, and vines. After the fall of the Western Empire the use of the leaden *bullæ* was assumed by the Popes, the oldest known being that of Deus dedit, A.D. 615-667, with a male figure standing between a lion and a lamb and A.Ω. Small seals were inscribed only with the names or monograms till Honorius II., 1124-30; but at the 12th century, the bullæ became larger, and the name of the pope appeared in full, with the heads of St. Peter and St. Paul, and a cross between them; the ordinal after the papal name dates from the 11th century. Besides these the Popes used the so-called seal of the Fisherman, or privy seal, on which was St. Peter fishing: this was impressed on red wax *en placard*. The use of the bullæ in Western Europe continued till the 16th century, the Emperors of Germany, princes of Calabria, the doges of Venice, dukes of Lorraine, and counts of Toulouse, continuing to use them. In the 13th century no priest was allowed to travel without a permission sealed with a leaden seal. The use of golden seals commenced about the 10th century, having been first used by the Byzantine Emperors and Charlemagne, Venetians and others, and occasionally for important documents as late as the 16th century, Henry VIII. and Francis I. having appended gold seals to their treaty at the Field of the Cloth of Gold. Silver seals were sometimes used by the Byzantine Emperors, the princes of Capua, and other Italian potentates. But all these were gradually superseded by wax seals. On the fall of the Roman Empire the art of seal engraving was lost in the West, but lingered at Constantinople. The early kings of France from Carloman, A.D. 769, to Louis VIII., 1176, used antique gems. Sealing *en placard* continued in France from Clovis I., A.D. 481, to Louis le Gros, 1108, in whose reign seals were first appended, and in Germany till the close of the 12th century.

The seals of the Merovingians represent busts with long hair, the Carlovingians bearded profiles, but appear to be impressions of ancient gems. The title of Dei gratia commences with Charlemagne; Hugh Capet, 987, is first seen with a sceptre. Robert has an oval pointed seal with a half-length figure. Henry I., 1031, was the first who used the seal of Majesty as it is called, representing the king seated on the chair of

Dagobert. Louis VI., 1108, is the only one with an equestrian figure on the reverse. Small counterseals on the reverse commence with Philip II., 1185. Louis IX., 1252, first appears with a crown fleury. John II., 1350, has two eagles' heads on his chair. Louis XII., 1500, a double gryphon. The king seated on the throne continued to be the type, with the exception of the great seal of Louis Philippe, which has on one side his head in profile, and on the other his arms or the two tables of the charter and law. The early seals of the German empire are like the French. Henry II. introduced the seated figure, which, after Frederick I., 1493, was abolished. Denmark used bronze seals; the Swedish seals resemble the German; those of Spain date from the 12th century; the doges of Venice, 1306, used gold bullæ.

The seal was placed after the name of the chancellor or his deputy in white wax; an incision in form of a cross, or with saltire edges turned back, having been made in the parchment and passed through, so as to form a cake or mass on both sides. This mode of sealing *en placard* being easily forged, the counter-seal was introduced by the princes of Lombardy, A.D. 901. The custom of appending seals was not introduced earlier than the 12th century; tails commenced in the 13th century, leather, hempen string, silk, parchment, were used for the purpose, and the seals were placed at the bottom, top, sides, or even all round the document. As many as 350 seals were appended to one document presented to the Council of Constance. Owing to the injuries to which seals were liable, it was not unusual from the 14th to the 16th centuries to protect them by a little frame work or torse of rush twisted round the seal; in the 14th century a wrapper of paper, neat bands of the same, beech, bay, and oak leaves, were placed over seals, and in France in the 15th century they were protected by tin boxes.

The French regal seals differ from the English and German by the use of the counterseal, which is not more than an inch in diameter; while the great seal of England retained an impression of the same magnitude on both sides. In France, during the 1st race, the seal was held by the *referendarius*, under the 2nd, or Merovingian, by the *archichancelier; aprocrisaire, archinotaire, archichapelain*, under the 3rd, or Capets, by the chancellor, who originally wore the seal round his neck, but when the seal became of large size, it was deposited in a box, and the chancellor always carried the keys about him in a purse, and the box was carried in certain ceremonies on a caparisoned horse. In this box were three others: 1st, for the great seal and counter-seal; the 2nd, that of Dauphigny; the 3rd, that of the order of St. Louis, besides which, the king had his private seal. Yellow wax was used for the impressions, except for ordinances, edicts, and letters entitled "à Tous presents et à venir," which were sealed with green wax, and the same colour was used for those of Dauphigny; other documents of which were sealed in red. In 1789, the office of chancery disappeared, but a new one was re-established in 1808, and superseded by a commission in 1811, and in 1830 incorporated with the office of minister of justice.

The earliest seals of the Anglo-Saxon monarchs, Offa, Ethelwolf, and Edgar, are *en placard;* of Coenwulf, 755, there is a leaden bulla; of Edward the Confessor, two wax seals pendent. Coke mentions seals of Edwy, A.D. 956, of Offa, A.D. 755-94. The Normans introduced wax seals, at first of moderate size, having on the obverse the king in armour on a caparisoned horse galloping, and on the reverse, the king seated on a throne, a type maintained to the present day. The expense of engraving a new matrix being very considerable, the monarchs were content to use those of their predecessors. Edward II. added to that of Edward I., and Edward III. used the same with the addition of two fleur-de-lis. Edward III. altered his seal eight times for political purposes. Richard II. used his father's last matrix, merely inserting his own name. Henry IV. and V., the same, by the same process. Henry VI. a new matrix, like the French, with a counter-seal. Edward IV. a new gold seal, like that of Bretigny; Edward V. his father's, and Richard III. the same. Henry VII. a new matrix, like that of Edward IV., and Henry VIII. one in the style of Francis I. The matrix of the seal of Henry IV. was of gold, the chancellor used a silver matrix, which was of 10 lbs. weight, and cost 13*l.* 10*s.* for material alone. The great seals of Scotland commence with Duncan II., 1096, with equestrian and seated royal figures. Alexander I., 1107, introduced the counter-seal. There were also great seals for Ireland, commencing with Henry II., a leaden matrix of which is known. There are, besides, the privy seals, having the royal arms only.

Next in importance to the royal seals are those of the ecclesiastical bodies and dignitaries. At first the bishops only used a private or peculiar seal, but at the close of the 9th century each prelate began to use a particular form of seal, in which was impressed the name and titles, and image, at first half length, then standing or seated, clad in his pontifical dress, and holding a crozier in one hand while giving the benediction, or holding the gospels in the other. During the 11th and 12th centuries the bishops were presented either standing or seated, but in the 13th and 14th the seated attitude specially designated the episcopal office. Sometimes the figures of the saints were substituted for those of the bishops. During the 13th century mottoes were introduced. In the 14th century the designs became more rich and varied, and in Germany the bishops and other religious functionaries placed their escutcheon on their seals beside their figure. In the 15th century the escutcheon, used at first only for the counterseal, became substituted for all other devices with few exceptions. Latterly the devices of the episcopal seals in France have been an imitation of those of the 13th century. The corporate seals of the abbeys, chapters, and other ecclesiastical bodies often have a representation of the religious edifices to which they belonged, or figures of the patron saints. The abbots and priors and prioresses often impressed their own images; the numerous minor functionaries were restricted to a device, or the figure of the patron saint.

The corporate seals of the 12th century have the towers, castles, gates, or city walls, the use of armorial bearings, which superseded ultimately all other subjects, not being older than 1365. The mayors and other municipal functionaries used a device or the city arms. In England the cinque ports have ships of war. The devices of the seals for the passes or passports of labourers were prescribed by the statute 12 Richard II., 1388.

The use of seals, as a legal formality, was introduced into England by the Normans during the 11th and 12th centuries. All persons of the ranks of knights and above used a horseman armed at all points going to the fight or chase; females had their effigies; but rude forms, birds, eagles, hawks, lions, dragons, crescents, and stars, are the common devices of the period. The legend surrounding the device, generally in Latin, contained the name and titles of the bearer. Secular persons used circular seals, ecclesiastics and women the pointed oval; counter-seals, *secreta*, do not occur earlier than 1170: the wax used was white bees'-wax, sometimes painted red, but green wax became common at the close of the 12th century; during the 13th and 14th centuries armorial bearings were introduced by the knights and others entitled to wear them, while the middle casses adopted arbitrary devices—fleur-de-lis, agnus dei, &c., grotesques, and emblems of their craft or calling. From the reign of Henry III. the style and art much improved; the shape of almost all the seals of this period is oval, the wax generally green, and the counterseal from the year 1200 in common use. After the year 1400, personal seals, not of an armorial character, decline in size and importance; and merchants' marks composed of monograms, introduced by the Flemings, are common devices of the 15th and 16th centuries. From the 12th to the 15th century antique gems set in silver were often used.

Personal seals have either the representation of the person to whom they belong, armorial bearings or arbitrary devices; only the nobility used personal effigies, as armed, on horseback, or holding their shields; ladies stand holding a bird or fleur-de-lis. Equestrian seals are circular, the others pointed. Armorial bearings begin in the 12th and continue till the 13th century; at the end of the 15th the middle class assumed coats of arms. Plain arms on pointed shields are the oldest; at the 15th century the shields are surrounded with drapery. They are generally orbicular, elliptic, or in form of a shield, and the matrices were flat, with a dorsal ridge and little ring; at the middle of the 14th, helms with feathers, crests, and support appear, and Gothic letters, which become common in the 15th century. Seals with grotesque devices and mottoes, assumed at pleasure, were in general use during the 14th and 15th centuries: love seals had two heads facing; and a favourite device was a squirrel. But after the 15th, and in the beginning of the 16th, a great change took place, the wax was covered with white paper and impressed, and at a later period wafers placed between paper were introduced, while sealing-wax was invented by Rousseau in the 17th century, and the seal, originally the substitute for the signature, at last degenerated into a legal formality and fiction.

The matrices of the early mediæval wax seals were made of lead for the middle and poorer classes, silver appears to have been used by the nobility; and in the 13th century a mixed metal resembling brass, long confined to Cologne, was used for the matrices; jet was used occasionally, and the matrices worn as amulets. The matrices are generally flat disks, about ½ inch thick, sometimes with a dorsal ridge and a ring or loop for suspension. The double seals have projecting rings at the sides, with pins for securing them when in the press. The shape varied at different epochs: under the Merovingians they were orbicular; under the Carlovingians, small oval. In the 14th and 15th century the sizes increased; but the ordinary forms are pointed vesica, oval, and angular; although trefoil, horseshoe, lozenge, square, octagonal, and other varieties occur. The matrices were sometimes forged, dies of Pius II. for making false bullæ having been found in London, and a false leaden matrix of Henry II. for Ireland still existing. The colour of the wax differed according to the period: white was employed by the French kings of the first three races, the emperors and prelates of Germany, till the 13th century; the kings of England from the time of Charles I., and some orders of knighthood. In France, Louis VII., A.D. 1137, first used red wax; William II., in England; and Frederick Barbarossa, in Germany; and monastic orders and territorial barons for judgments, quittances, and other charters during the 14th and 15th centuries. Philip Augustus, A.D. 1180, first employed green wax, which was also used by the nobility and ladies. Black was employed by the Teutonic order in the 13th century. The form of the letters of the inscriptions changed from time to time; Roman capitals were in use till the 12th century, when Gothic letters commenced with the form SI, SIG, or SIGILLVM; and in the 14th century the legend was preceded by a cross +, and later by a rosette or star. Latin was the language usually employed. The name of the seal was sometimes on the legend, as *sigillum com-*

mune, common seal; *sigillum secretum*, privy seal; *contrasigillum*, counterseal. The early French seals have invocations, as *Christe protege Pippinum Regem*, "God save king Pepin."

In England, the seals of conveying parties are now essential to all legal instruments whereby real estate is conveyed. The law recognises three royal seals, the great seal in custody of the chancellor, attached to all letters patent, grants of inheritance, or chattels real, offices in fee and writs at common law, the privy seal kept by the Lord Keeper, valid for the issue of treasure, disposition of chattels, contracting or discharging a debt; the signet, or privy signet in custody of the principal secretaries of state, valid as authenticating the sign manual, and for the writ *ne exeat regno*. The counter signature of a principal secretary of state is required by a statute for the use of all the seals. (Comyn, 'Digest,' Patent; Coke upon Littleton, by Hargrave and Thomas, ii. 233.)

Among oriental nations seals have been employed as a stamp. The Chinese great seal called *se* dates from the Tsin dynasty, B.C. 248, under whom they were square; under the Hân dynasty they became circular. Other seals *yin* are generally square and made of gold, silver, copper, crystal, porcelain, steatite, wood, and other substances, of tall rectangular shape, surmounted by figures of lions, apes, dragons, and other animals. They generally have mottoes or sentences from Chinese classical authors, and impressions in various coloured inks are stamped in important places on commercial and public documents, books, and papers. The Arabs and Indians, from the earliest times, have used metal seals and gems to impress by means of black ink impressions on their books and other documents; only wax has, however, been used in modern times.

The study of seals is one of the most important in archæology; after the fall of the Roman Empire they replace the loss of gems and show the state of the glyphic art; of architectural progress; of Christian symbolism till the present day; at the same time throwing great light on the history of states and families, their heraldic devices and genealogy.

Mabillon, *De re diplomaticâ*, fo. Par. 1681; the Benedictins' *Traité de diplomatique*, 4to Par., 1759; De Wailly, *Elements de Palæographie*, 4to, Paris, 1858, vol. ii.; *Travaux de la Société Sphragistique de Paris*, 1852; *Proceedings of the Archæological Institute*, London, 1836-61.

SEALING-WAX. The best red sealing-wax is composed of shell-lac, Venice turpentine, and cinnabar. The shell-lac by itself is rather too brittle, and the turpentine is added to remedy that defect. The proportions are about four parts of lac, one part of turpentine, and three parts of cinnabar, by weight. When the lac and turpentine are melted, the cinnabar is added in powder, and the whole is well mixed by stirring it about. The round sticks of sealing-wax are made by hand on a smooth slab of marble or plate of metal, which is kept at a moderate temperature by a brazier placed beneath it. The liquid sealing-wax having been partially cooled, a quantity sufficient to make about six sticks is rolled out on the slab or plate into one long stick; which, when of proper diameter, is cut into lengths, and transferred to another workman, by whom the sticks are rolled on a cold slab beneath a smooth piece of wood or metal. The sticks are now polished, which is done by holding them successively between two contiguous charcoal fires till the surface is fused, which produces the polish. One end is then softened by being brought near the flame of a lamp, in order to receive the impression of the maker's name. This manipulating process is only applied to the round sticks; those which are oval and ornamented are formed by pouring the liquid sealing-wax into a mould; when partly cooled, the sticks are removed to another mould made of steel, out of which they are taken polished and fit for use.

For the best black sealing-wax, the finest ivory-black is substituted for the cinnabar. For sealing-wax of inferior quality, not only the darker-coloured shell-lac is used, but other resins of less value, common turpentines, and mixtures of cinnabar and red lead, or sometimes red lead alone; and lamp-black is used instead of ivory-black. Other colours are given to sealing-wax by mixing with it, for the most part, different metallic oxides.

The softer wax, which was formerly in general use for sealing letters and legal documents, and which is still occasionally used for the latter purpose, consists of about four parts of bees'-wax, one part of Venice turpentine, and as much cinnabar or other colouring material as is required to give it the tint which is preferred.

SEAMEN. [SHIPS.]

SEARCH, RIGHT OF. The general principles upon which that part of the law of nations is constructed which respects the usages to be observed towards neutral powers in time of war by the belligerent powers, have been explained under the head of BLOCKADE. Here it is only necessary further to remark that manifestly no other right can be exercised by the belligerent over the ships of the neutral without the right of visitation and search. The existence of that right, accordingly, to use Lord Stowell's language in the well-known case of the Maria (1 Robinson, 340), is acknowledged beyond all controversy as attaching to the lawfully commissioned cruisers of the belligerent nations, whose rights cannot legally be varied by the interposition, in any manner of mere force, of the authority of the sovereign of the neutral country: a right that is as reasonable as it is necessary, for, as his lordship says, "Till they are visited and searched, it does not appear what the ships, or the cargoes, or the destinations are; and it is for the purpose of ascertaining these points that the necessity of this right of visitation and search exists."

In the exercise of the right of search upon a neutral vessel, which must be conducted with as much regard to the rights and safety of the vessel detained as is consistent with a thorough examination of her character and voyage (the Anna Maria, 2 Wharton's (Amer.) Rep. 332), the first and principal object of inquiry is generally the ship's papers. These are, the passport from the neutral state to the captain or master; the sea letter, or sea brief, specifying the nature and quantity of the cargo; the proofs of property; the muster-roll of the crew, containing the name, age, rank or quality, place of residence, and place of birth of each of the ship's company; the charter party; the bill of lading; the invoices; the log-book; and the bill of health. (Abbott, 'On Shipping,' 9th edit., 288.) Upon the subject of the ship's documents, it should be observed, that if she is not properly documented, or if there has been a spoliation of papers, and other signs of bad faith, these are grounds of unfavourable presumption, the effect of which is not to be avoided except by clear and satisfactory evidence to the contrary. (M'Lachlan, 'Law of Merchant Shipping,' p. 481.)

The penalty for the violent contravention of the right of visitation and search, is the confiscation of the ship and cargo; and a rescue by the crew after the captors are in actual possession is considered as the same thing with a forcible prevention. In either case the resisting ship may be seized in the same manner as if it belonged to the enemy, and, being brought into port, will be condemned as prize.

Of course, any of the belligerent powers may agree with any of the neutral states that the right of search shall only be exercised in certain circumstances; and this is the first limitation that falls to be noticed. "Two sovereigns," Lord Stowell has said in the same judgment, "may unquestionably agree, if they think fit, as in some late instances they have agreed, by special covenant, that the presence of one of their armed ships along with their merchant-ships shall be mutually understood to imply that nothing is to be found in that convoy of merchants' ships inconsistent with amity or neutrality; and, if they consent to accept this pledge, no third party has a right to quarrel with it, any more than with any other pledge which they may agree mutually to accept. But surely no sovereign can legally compel the acceptance of such a security by mere force. The only security known to the Law of Nations upon this subject, independent of all special covenant, is the right of personal visitation and search, to be exercised by those who have the interest in making it." Lord Stowell here alludes to the pretensions of the northern powers in their convention for the establishment of what was called an armed neutrality in 1800, one of the clauses of which was, "That the declaration of the officers who shall command the ship of war, or ships of war, of the king or emperor, which shall be convoying one or more merchant-ships, that the convoy has no contraband goods on board shall be sufficient; and that no search of his ship, or the other ships of the convoy, shall be permitted." It is sometimes stated that this was also one of the principles of the previous convention of the same kind formed by the northern powers in 1780; and there may perhaps have been an understanding among the contracting parties to that effect; but we do not find it distinctly avowed in any of their published announcements. The position in question, namely, that the presence of a ship of war should protect from search the merchantmen under its convoy, never has been admitted by Great Britain.

But it is now universally admitted that the right of visitation and search cannot be exercised upon a ship of war, or public or national vessel, itself; and this is the second limitation of the right. It is strange that there should ever have been any doubt or dispute upon this point. A ship of war has always been looked upon as in a manner part of the national territory, and as such inviolable in any circumstances whatever; the act of entering it in search either of contraband goods or of deserters must be considered as an act of the same character with that of pursuing a smuggler or fugitive across the frontier of the state without permission of the sovereign authority, a thing the right of doing which has never been claimed. Accordingly, although it has been a common thing for nations to declare by express stipulation in their treaties with one another that the prize courts in each shall exercise a jurisdiction according to the recognised principles of public law in questions arising with regard to captures at sea, the language used has always implied that the captures are to be merchant or private vessels: of the concession by one power to another of the right of adjudicating upon its ships of war detained or brought into port not a trace is to be found in any such treaty. Yet an opposite doctrine has been both maintained in argument, and attempted to be carried into effect. In 1653, when after the disasters of the war with England that had broken out in the preceding year, the Dutch were reduced to such a state as to make them anxious for peace upon almost any terms, the English government demanded as one of the stipulations of the proposed treaty that all Dutch vessels, both of war and others, should submit to be visited, if thereto required. But, humbled as the Dutch were, they peremptorily refused to agree to any such stipulation; and the treaty was concluded in 1654 without it. From this time, for more than a century and a half, the principle of the immunity of ships of war from visitation and search was acquiesced in by the practice of our own and every other country, nor is it known to have been contested even in speculation. But at length, in the course of the controversy that arose respecting the rights of neutrals out of the Berlin and Milan decrees of the French emperor and our own orders in council, in 1806 and 1807 [Blockade], while some extreme partisans on the one side contended that even merchant ships were not liable to search when under the convoy of a man-of-war, others on the opposite side revived the old pretension of the English republican government of 1653, and maintained our right of visiting and searching the ships of war themselves of neutral states whenever we should think proper. The practical application of the principle that was now especially called for was the visitation of the ships of war of the United States of America, for the purpose of recovering seamen alleged to be subjects of this country and deserters from the British service. An actual enforcement of the new doctrine occurred in an attack made, on the 23rd of June, 1807, by the British ship of war, Leopard, upon the American frigate Chesapeake, lying off the Capes of Virginia. On the refusal of the American captain to permit his ship to be visited, the Leopard fired into the Chesapeake, which, being unprepared for action, immediately struck her flag. Four men were carried off, and the American ship was then left. The American minister in London was directed to demand satisfaction of the British government. Negociations were continued for a long time without any result; the affair of the Chesapeake soon became mixed and complicated with other incidents, giving rise to new claims and counterclaims; at last the American government took its stand on new ground, objecting to the search not only of ships of war but even of merchant vessels for deserters; it was not denied that the search of merchantmen was sanctioned by the law of nations, but the exercise of the right was denounced as necessarily irritating and fraught with danger, and it was urged that it should on that account be dispensed with and abolished. In the end war broke out between the two countries in the summer of 1812; but even that did not settle any of the questions that had arisen between them in connection with the right of search. The treaty of peace signed at Ghent on the 24th of December, 1814, contained no stipulation on that subject, which was now supposed to have lost its practical importance. This question was again incidentally raised between England and America in 1842. In the discussion which then took place between Lord Ashburton and Mr. Webster relative to the boundary line of the state of Maine, the American minister intimated that the rule hereafter to be insisted upon would be that every regularly documented American vessel would be evidence that the seamen on board were American, and would find their protection in the flag that was over them; and again in 1854, when, after the issuing of the declaration by the Queen of England (on the 28th March), it was supposed to be her Majesty's intention to relax the right of search, the Attorney-General stated in answer to a question in the House of Commons (30th March), "That it never was intended to give up, nor did the declaration give up, the right of searching neutral vessels. It was impossible to give up that right, and this country still maintains its right to search and seize vessels which carry enemy's despatches, or articles contraband of war." But whilst England thus reserved to itself this right, she waived its exercise during the war, and on the termination of hostilities, concurred with France, Austria, Russia, Prussia, Sardinia, and Turkey, in establishing the principle that "free ships make free goods."

The maritime declaration appended to the Treaty of Paris comprises among others the following points:—

1. The neutral flag covers enemy's goods, with the exception of contraband of war.

2. Neutral goods, except contraband of war, are not liable to capture under the enemy's flag.

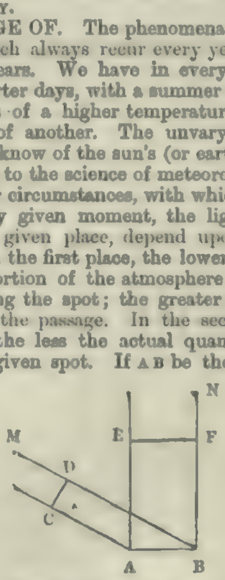
The United States, however, refused to concur in this declaration, unless it was further conceded that enemy's goods on board enemy's merchant ships should be allowed the same exemption as on board neutrals.

At present therefore it appears that the right of search, abolished so far as relates to *enemy's property* on board neutral ships by the Treaty of Paris, subsists as to the other points in respect of which it was formerly exercised, namely, the carriage of troops, hostile despatches, and contraband of war. (Arnold on 'Marine Insurance,' vol. i. p. 673.)

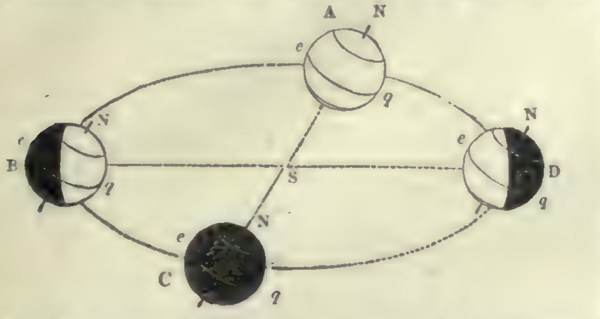
The right of visitation and search, however, is by no means necessarily confined to a time of war. Its exercise has always been admitted to be equally allowed by international law in time of peace, though it may not commonly have then been so frequently thought to be called for. The very question of the seizure by one country of its subjects serving in the mercantile navy of another, which was one of the main subjects of dispute between England and America before the breaking out of actual hostilities in 1812, may arise in a time of peace as well as in a time of war, though its importance no doubt is less in the former than in the latter. The chief questions connected with the right of search, the number of which is greatly reduced in a time of general peace, are those relating to the trading rights of neutrals; but even of these some remain. Of late years, however, the right of search has become principally important in reference to the trade in slaves, which has now been declared to be illegal by most of the great maritime states. The right of visitation and search, however its exercise may be regulated, seems to afford the only means of ascertaining whether or no a vessel has got slaves on board; but it is evident that any power opposed, for whatever reason, to the exercise of that right may, even while declaring the slave trade to be illegal, refuse to allow that illegality to be made an excuse for the visitation of suspected ships bearing its flag. It is only by express stipulation that the free exercise of the right can be established. England, which has all along been foremost in the attempt to suppress the slave trade, has never objected to the exercise of the right of search for this, or indeed for any other legitimate object; but other nations, jealous of our predominant maritime power, have, not perhaps very unnaturally, been extremely reluctant to concede it in this particular case. Probably the best illustration of these remarks is afforded by the Ashburton Treaty, and the attitude of American publicists with reference to it. By the 8th article of that treaty, each party was to maintain a separate squadron on the coast of Africa for five years, and the cruisers of the respective nations were to detain all vessels under American colours equipped for, and engaged in, the slave trade; that if proved to be American property they should be delivered to an American cruiser; and if proved to be Spanish, Portuguese, Brazilian, or English property, to an English cruiser. In the President's message (August 11, 1842), and in the discussions in the American House of Representatives, it was maintained, or attempted to be maintained, that the 8th article was a substitute for visitation and search; but Sir R. Peel emphatically declared that in acting upon the treaty England had not abandoned her claim to the right of visitation; and Lord Aberdeen's despatch, re affirming the British doctrines on this subject, recorded the determination of England not to depart from the principles she had constantly asserted. Upon this treaty, the debates in the British Houses of Parliament, the expressed opinion of the British Government, and the instructions to its cruisers, considerable discussions have been raised, and attempts have been made by American writers (among whom Mr. W. B. Laurence's recent treatise on 'Visitation and Search' deserves special notice) to show that the doctrines of England are unwarranted by law, dangerous to the welfare of other countries, and intended solely to promote the attainment of universal dominion under the guise of humanity; that the time has come when such doctrines must be energetically opposed, and that if they can be supported by an appeal to the language of treaties, then it is the duty of the States of the Union to insist upon the discontinuance of those treaties.

Some further remarks on this subject are briefly made under the article Slave, Slavery.

SEASONS, CHANGE OF. The phenomena of the seasons may be divided into those which always recur every year and those which are different in different years. We have in every year the same succession of longer and shorter days, with a summer and winter; while the summer of one year is of a higher temperature, and accompanied by finer days, than that of another. The unvarying phenomena can be explained by what we know of the sun's (or earth's) motion; the varying phenomena belong to the science of meteorology, and depend upon atmospheric and other circumstances, with which we have little or no acquaintance. At any given moment, the light and heat received from the sun, at any given place, depend upon the altitude of that body in two ways. In the first place, the lower the sun is, the greater the thickness of the portion of the atmosphere which its rays have to traverse before reaching the spot; the greater then is the light and heat which is lost in the passage. In the second place, the less the altitude of the sun, the less the actual quantity of light and heat which falls upon any given spot. If A B be the diameter of a circular portion of the earth's surface, and if the sun be seen in the direction B M, the light which falls on that circle is a cylinder of rays with the diameter C D; but if the sun be seen vertically, or in the direction B N, the cylinder of rays has E F for its diameter, besides which, the rays of the first cylinder are weaker than those of the second, as having passed through more of the atmosphere. Neglecting this latter consideration, the quantities of light and heat received when the sun is at two different altitudes are as the sines of those altitudes. Thus the sine of 30° being ½ and that of 90° being 1, the quantity of light which falls on a given spot when the sun is vertical is double of that which falls when its altitude is 30°.



The earth's axis preserves its direction throughout the whole of the yearly motion. The consequence is, that places which are distant from the equator have very unequal days at different times of the year. [Sun.] The accompanying figure, which is generally given in connection with this subject, represents the earth in its four principal positions; the sun being at S, and N being the north pole of the earth. A is at the vernal equinox, the intersection of the equator and ecliptic passes through the sun, and days and nights are equal all over the world. B is at the summer solstice, where the sun is most above the equator on the northern side; the diurnal circles north of the equator have more day than night, and have their longest days: and *vice versâ*. C is the autumnal equinox, the phenomena of A being repeated. D is at the winter solstice, where the sun is farthest from the equator on the southern side; the phenomena of B are now reversed, the days being shortest on the north side of the equator. This figure very well explains the variation of days and the main reason for the phenomena of seasons in the extra-tropical parts of the earth. It is evident that, speaking of the northern hemisphere, the sun, being above the equator, gives not only longer days, but greater altitudes; more powerful light and heat, and more of it in duration.



The average temperature being nearly the same in different years, the northern side of the earth must be receiving more than it parts with during a portion of the year, and parting with more than it receives during the remainder. The summer half of its year is that half during which it gains on the whole, more than it parts with; the surplus being that which is lost during the winter half. The day in which most heat is received is the longest day; but it is notorious that the hottest weather is generally some time after the longest day. This is easily explained, as follows:- The time of the greatest heat is not that at which most heat is received, but that at which the quantity of heat is the greatest, namely, just before the daily receipts of heat begin to fall short of the daily expenditures. So long as the receipt exceeds the expenditure, heat is daily added to the hemisphere, and the weather becomes hotter. The same reason may be given for the greatest cold generally following the shortest day, with a considerable interval. All these circumstances, however, depend much on the atmospheric circumstances of the year.

The preceding explanation does not serve for the tropical climates, the days and nights are here so nearly equal throughout the year, that seasons are caused more by the effect of the winds (which are very regular, and depend mainly on the sun's position) than by changes in the direct action of the sun's light and heat. The seasons are not a summer and a winter, so much as recurrences of wet and dry periods, two in each year.

With regard to the quantity of heat received in a day, it might be expressed, so far as it is not modified by the atmosphere, in a formula depending on the latitude of the place and the sun's declination. It will be enough to say that this formula shows that, the sun being in the equator, the day's heat in different places is as the cosine of the latitude; and that for all places at the equator, the day's heat for different days is as the cosine of the sun's declination.

The different distances at which the earth is from the sun, at different times of the year, do not affect the heat received in a given portion of the orbit. The sun is nearest to the earth in our midwinter, but for that reason the winter is shorter, since the earth moves more rapidly when nearer to the sun. The compensation is exact, for the quantity of heat received at any one moment, while the radius of the earth's orbit moves through any small angle, is greater or less in the inverse proportion of the square of that radius. But the time of describing that angle is less or greater in the direct proportion of the same square. Consequently the heat actually received by the earth in the two halves of its orbit is the same in both.

SEAT (in a church). [PEW.]

SEAWORTHINESS. [SHIPS.]

SEBACIC ACID. [SEBACIC GROUP.]

SEBACIC GROUP. A small class of chemical compounds belonging to the pelargonic series in Gerhardt's arrangement. The principal member is sebacic acid

Sebacic acid ($C_{20}H_{16}O_6$, 2HO) or *pyroleic acid* is always obtained when oleic acid or an oil containing oleic acid is distilled. It is most advantageously prepared by the action of a hot and very strong solution of caustic potash upon castor oil. The ricinolic acid of the castor oil is thus split up into sebacic acid, caprylic alcohol, and free hydrogen. Sebacic acid is soluble in hot water, and crystallises out from a boiling solution of the sebate of potash, produced as just indicated, on the addition of hydrochloric acid. It forms white lamellar or acicular crystals, of the appearance of benzoic acid; is very soluble in alcohol, ether, or oils; reddens litmus paper; melts when heated to 260° Fahr., and at a higher temperature sublimes. Nitric acid converts it into succinic acid.

Sebacic acid is bibasic, forming neutral *sebates* of the formula 2MO, $C_{20}H_{16}O_6$; and acid salts containing MO,HO,$C_{20}H_{16}O_6$. The alkaline salts are nearly all crystalline and soluble in water; from them the other sebates are prepared by double decomposition. *Sebate of methyl* or *methyl sebacic ether* contains $C_{20}H_{16}(C_2H_3)_2O_8$; by contact with ammonia it gradually yields *sebamide* ($C_{20}H_{20}N_2O_4$) in crystalline grains, the mother liquor containing *sebamic acid* ($C_{20}H_{19}NO_6$).

Ipomic acid seems to be identical with sebacic acid. Jalap (ipomea purga) resin yields rhodeoretic acid when acted on by bases, and rhodeoretic acid furnishes ipomic acid on being oxidised by nitric acid. The fusing point of ipomic acid is 40 degrees below that of sebacic acid, but in every other respect it resembles the latter body.

SEBAMIC ACID. [SEBACIC GROUP.]

SEBAMIDE. [SEBACIC GROUP.]

SEBAT (in Hebrew, שְׁבָט), is the fifth month of the civil year of the Jews. The name is mentioned in the 7th verse of the 1st chapter of Zechariah, where it is called the eleventh month, reckoning from the vernal equinox, at which season the Jews anciently began their year. It is called Sabat in the Apocrypha, at 1 Macc. xvi. 14. The name is found at Palmyra written as in Hebrew, and at Balbek it was written Σοβαδ. Sebat has thirty days; its place in the year varies from January to February, and in 1860 it began on the 25th of January and ended on the 23rd of February. In 1861 it began on the 12th of January and ended on the 10th of February. A fast is mentioned in some calendars on the 4th day of Sebat, for the wickedness of Israel after the death of Joshua, and another on the 23rd day, in memory of the war between the tribe of Benjamin and the rest of the nation, related in the 20th chapter of Judges; but these fasts are observed very partially, if at all.

SEBIN. ($C_{32}H_{30}O_{16}$). The sebate of glycerin. It is neutral and crystalline, and is transformed by oxide of lead into sebacic acid and glycerin.

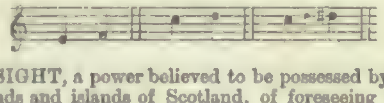
SECALE CORNUTUM. [ERGOT.]

SECANT, a line which cuts another; also a term in TRIGONOMETRY.

SECEDERS. The origin and history of the Seceders from the Established Church of Scotland will be found briefly stated in the article UNITED PRESBYTERIAN CHURCH, that being the name adopted by the religious fellowship which includes the greater number of Seceders. The *Synod of United Original Seceders*, the only body which retains the name Seceders in its official designation, professes the same doctrine and discipline as the United Presbyterian Church, but maintains the principle of a national church, and also that of national religious vowing or covenanting. The Original Seceders number about 30 congregations, forming 4 presbyteries. Since the disruption in 1843 [FREE CHURCH OF SCOTLAND], many of those known as Original Seceders and Associate or Old Light Burghers, have joined the Free Church, on the ground of its being, in their judgment, the true National Reformed Church of Scotland.

SECOND, the sixtieth part of a minute, whether of time or of angular measure. [ANGLE; TIME.] For the derivation of this word, see SCRUPLE.

SECOND, an interval in music, a discord, the ratio of which is 9 : 8. Of seconds there are three kinds: the minor second, or semitone, as E F; the major second, C D; and the extreme sharp second, C D; Ex.:—



SECOND-SIGHT, a power believed to be possessed by some persons in the highlands and islands of Scotland, of foreseeing future events, especially of a disastrous kind, by means of a spectral exhibition of the persons whom these events respect, accompanied with such emblems as denote their fate.

Jamieson says, "Whether this power was communicated to the inhabitants of the highlands and islands of Scotland by the northern nations, who so long had possession of the latter, I shall not pretend to determine; but traces of the same wonderful faculty may be found among the Scandinavians. Isl. *ramskygn* denotes one who is endowed with the power of seeing spirits: 'qui tali visu præter naturam præditus est, ut spiritus et dæmones videat, opaca etiam visu penetret.' Verel. Ind. The designation is formed from *ramm-ur*, viribus pollens, and *skygn*, videns; q. e. powerful in vision."

Dr. Johnson, in his journey to the Western Islands of Scotland, carefully examined the questions of the second-sight; but neither he nor Dr. Beattie could find sufficient evidence of its reality.

In Sir John Sinclair's 'Statistical Account of Scotland,' vol. iii., 8vo., Edinb., 1792, the minister of Applecross, in the county of Ross, speaking of his parishioners, says, "with them the belief of the second-sight is general."

In MacCulloch's 'Western Islands of Scotland,' 8vo., Lond., 1819, vol. ii., the author says, "To have circumnavigated the Western Isles without even mentioning the second-sight would be unpardonable. No inhabitant of St. Kilda pretended to have been forewarned of our arrival. In fact it has undergone the fate of witchcraft; ceasing to be believed, it has ceased to exist."

In the Erse the second-sight is called *Taisch*.

SECONDARY, a name given to any circle on the sphere with reference to another circle: if the latter be called primary, the former is secondary when it passes through the poles of the primary. [Sphere.]

SECONDARY COIL, CURRENTS, &c. [Magneto-Electricity.]

SECRETARY (French, *Secrétaire*), one entrusted with the secrets of his office or employer; one who writes for another. Its remote origin is the Latin *secretum*. The phrase "notarius secretorum" is applied by Vopiscus ('Div. Aurelianus') to one of the secretaries of the emperor Aurelian. This appellation was of very early use in England: Archbishop Becket, in the reign of Henry II., had his "secretarius;" although the person who conducted the king's correspondence, till the middle of the 13th century, was called his clerk only, probably from the office being held by an ecclesiastic. The first time the title of "secretarius noster" occurs is in the 37th Hen. III., 1253.

SECRETARY OF STATE. The office of secretary of state is one of very ancient date, and the person who fills it has been called variously "the king's chief secretary," "principal secretary," and, after the Restoration, "principal secretary of state." He was in fact the king's private secretary, and had custody of the king's signet. The duties of the office were originally performed by a single person, who had the aid of four clerks. The statute 27 Henry VIII., c. 11, regulating the fees to be taken by "the king's clerks of his grace's signet and privy seal," directs that all grants to be passed under any of his majesty's seals shall, before they are so sealed, be brought and delivered to the king's principal secretary or to one of the clerks of the signet. The division of the office between two persons is said to have occurred at the end of the reign of Henry VIII., but it is probable that the two secretaries were not until long afterwards of equal rank. Thus we find Sir Francis Walsingham, in the time of Queen Elizabeth, addressed as her majesty's principal secretary of state, although Dr. Thomas Wilson was his colleague in the office. Clarendon, when describing the chief ministers at the beginning of the reign of Charles I., mentions the two secretaries of state, "who were not in those days officers of that magnitude they have been since; being only to make despatches upon the conclusions of councils, not to govern or preside in those councils." Nevertheless the principal secretary of state must, by his immediate and constant access to the king, have been always a person of great influence in the state. The statute 31 Henry VIII., c. 10, gives the king's chief secretary, if he is a baron or a bishop, place above all peers of the same degree; and it enacts that if he is not a peer, he shall have a seat reserved for him on the woolsack in parliament; and in the Star Chamber and other conferences of the council, that he shall be placed next to the ten great officers of state named in the statute. He probably was always a member of the privy council. Cardinal Wolsey in his disgrace earnestly implores Secretary Gardiner (afterwards bishop of Winchester), whom he addresses as a privy councillor, to intercede for him with the king. (Ellis's 'Letters,' vol. ii.) Lord Camden, in his judgment in the case of Entick *v.* Carrington (11 Hargrave's 'State Trials,' p. 317), attributes the growth of the secretary of state's importance to his intercourse with ambassadors and the management of all the foreign correspondence of the state, after the policy of having resident ministers in foreign courts was established in Europe. Lord Camden indeed denies that he was anciently a privy counsellor.

The number of secretaries of state seems to have varied from time to time: in the reign of George III. there were often only two; but there are now five principal secretaries of state, whose duties are divided into five departments, namely, for home affairs, foreign affairs, for war, for the colonies, and a fifth, first appointed in 1858, for the management of the affairs of India. They are always made members of the privy council and the cabinet. They are appointed (without patent) by mere delivery to them of the seals of office by the sovereign. Each is capable of performing the duties of all the departments, and the offices are all so much counted to be one and the same, that if removed from one secretaryship of state to another, a member of the House of Commons does not vacate his seat.

To the secretary of state for the home department belongs the maintenance of the peace within the kingdom, and the administration of justice so far as the royal prerogative is involved in it. All patents, charters of incorporation, commissions of the peace and of inquiry, pass through his office. He superintends the administration of affairs in Ireland. The secretary for foreign affairs conducts the correspondence with foreign states, and negotiates treaties with them, either through British ministers resident there, or personally with foreign ministers at this court. He recommends to the crown ambassadors, ministers, and consuls to represent Great Britain abroad, and countersigns their warrants. The secretary for the colonial department performs for the colonies the same functions that the secretary for the home department performs for Great Britain. The secretary for war has the management of the army, in which he has the assistance of the commander-in-chief. Each is assisted by two under-secretaries of state, nominated by himself; the one being usually permanent, the other dependent upon the administration then in power. The secretary for India has one under-secretary, and the assistance of a council. There is likewise in each department a large establishment of clerks appointed by the principal secretary.

The power to commit persons on suspicion of treason is incidental to the office of principal secretary of state—a power which, though long exercised, has been often disputed. It is not necessary here to give the arguments on both sides; they are discussed with great care by Lord Camden in the case above cited (Entick *v.* Carrington), which was one of the numerous judicial inquiries arising out of the dispute between the Crown and John Wilkes at the beginning of the reign of George III. The conclusions to which Lord Camden comes are—that the secretary of state is not a magistrate known to the common law; that the power of commitment for state offences, which he has for many ages exercised, was used by him as an immediate delegation from the person of the king, a fact which may be inferred, among other things, from the debates in parliament in the time of Charles I., when Secretary Cook claimed the power on that ground; that nevertheless courts of justice must recognise this power, inasmuch as there has been constant usage of it, supported by three judicial decisions in favour of it since the Revolution, namely, by Lord Holt in 1695 (Rex *v.* Kendal and Rowe); by Chief Justice Parker in 1711 (Queen *v.* Derby); and by Lord Hardwicke in 1734 (Rex *v.* Earbury). In a more recent case (King *v.* Despard, 1798), Lord Kenyon says, "I have no difficulty in saying that the secretaries of state have the right to commit," and he hints that Lord Camden felt too much doubt on the subject.

There is also a chief secretary for Ireland, resident in Dublin (except when parliament is sitting), and having always an under-secretary there. He corresponds with the home department, and is under the authority of the lord lieutenant. His office is called that of secretary to the lord lieutenant; but it is analogous to the office of secretary of state. He has sometimes, though very rarely, been a member of the cabinet.

SECT (from the Latin *Secta*). Two accounts are given of the origin of this word. By some persons it is represented as a derivative of *sequ-or* (*secu-tus*), "to follow." By others it is derived from *sec-o* (*sec-tus*), "to cut." It is in this case, as in many similiar instances, not easy to decide between the pretensions of the two; and it is far from being improbable that some persons may have used the word as a derivative from one verb, and others as derived from the other.

The *sects* of philosophers in ancient times seem rather to have been persons who were *followers* of some distinguished teacher, than persons *cut off* from any general mass. But when we come to the word in its now more common and familiar use, namely, as denoting a particular community of Christians, the idea then predominates of *separation, cutting off*, over that of *following*. Thus no one thinks of calling the Roman Catholic church a sect: and none, except it was designed to disparage and dishonour it, would call the English Protestant church a sect. But when we descend below it, we then see smaller religious communities, who are *cut off* from a church, either by their own act, or by some supposed or real act of usurpation and unchristian tyranny on the part of the larger community. Thus the Quakers are a sect, the Anabaptists are a sect, the Methodists are a sect, and the Independents and English Presbyterians now are sects, though some of these were for a time in existence without falling under the description of a sect, being still incorporated in the church, in which they sought to accomplish certain reforms. In other systems there are smaller bodies of sectaries.

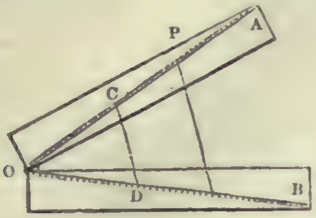
SECTION, the curve made by the intersection of two surfaces. In the graphical arts it means generally a plane section, and most frequently a vertical section, the horizontal section being called the plan. In architectural designs, the longest vertical section is usually called the elevation, the term section being restricted to vertical sections which are perpendicular to the elevation.

SECTOR (Geometry), the figure made by two straight lines which meet, and a curve which cuts them both. The most common is the circular sector, made by two radii of a circle and the arc which they include. If r be the radius in linear units, and θ the angle measured in *theoretical* units [Angle], the area of the sector is $\frac{1}{2} r^2 \theta$ square units; but according as the angle is expressed in degrees and fractions of a degree, in minutes and fractions of a minute, or in seconds and fractions of a second, the area is found by the first, second, or third of the following formulæ:—

$$\frac{r^2\,\theta^\circ}{2 \times 57{\cdot}29578} \qquad \frac{r^2\,\theta'}{2 \times 3437{\cdot}747} \qquad \frac{r^2\,\theta''}{2 \times 206264{\cdot}8}$$

SECTOR (drawing instrument), an instrument invented by Gunter, which has the appearance of a small carpenter's rule, marked with scales in every part; the greater number of these scales not being laid down parallel to the edges of the rule, but converging towards the pivot on which the moving arm of the rule turns while the instrument is opened. Only these converging scales properly belong to the sector; the others are merely laid down for convenience on such blank spaces as are left by the converging or sectorial scales.

The sector is a large number of pairs of compasses packed up into one, and most explanations of the instrument attempt to describe them all in one. It will, however, be more convenient to separate one pair of compasses from the rest, and to describe its use. Each piece of the ruler is marked with the same scales. Take one of these scales, O A, and that which corresponds to it, O B; then A O B is a pair of compasses which can be opened or shut at pleasure. Suppose two scales, say of chords, to be laid down on O A and O B, which are chords of 90°,



O P and O Q being radii, or chords of 60°. If O P be four inches, we have then before us two scales of chords with the radius of four inches actually laid down, and any chords might be taken off them as from a common scale: for instance, if the marks of 35° be at C and D, then either O C or O D is the chord of 35° to a radius of four inches. But suppose it required to find the chord of 35°, not to a radius of four inches, but to one of 3·61 inches. We know that

$$4 : 3{\cdot}61 :: \text{ch. } 35° \text{ (rad. 4)} : \text{ch. } 35° \text{ (rad. } 3{\cdot}61\text{)};$$

and the fourth term of this proportion is to be found. Now this may be done with sufficient accuracy, and without any drawing, as follows:— Take a common pair of compasses, and open them to 3·61 on a subdivided scale of inches. Then open the sector until the points of the compasses are made to fall on P and Q, which, if the sector open rather easily, may be done very quickly. We have then $PQ = 3{\cdot}61$ inches, and C D is the chord of 35° to that radius; for by similar triangles

$$\begin{gathered} OP : PQ :: OC : CD; \\ \text{or, } 4 : 3{\cdot}61 :: \text{ch. } 35° \text{ (rad. 4)} : CD; \\ \text{whence, } CD = \text{ch. } 35° \text{ (rad. } 3{\cdot}61\text{)}. \end{gathered}$$

Take the compasses then, and fixing one point at C, make the other fall on D; the distance C D may then be transferred with the compasses to the paper, or to the scales of inches, according as construction or arithmetical estimation is required.

The scales usually laid down upon the two sides of common sectors, such as are constructed upon a foot ruler, are:—

1. A line of *polygons*, marked POL., showing the sides of polygons inscribed in a circle. And since the side of the hexagon is the radius of the circle, the radius of the scale is the distance from O to the figure 6. Thus, to inscribe a polygon of ten sides in a circle of two inches radius, open the sector until 6 and 6 on the counterpart polygon scales are two inches apart: then the distance from 10 to 10 on the same scales will be the side of the figure required.

2. A line of *chords*, as above described, the radius being the chord of 60°. But it is to be noted that upon the common sector the whole length O A of the scale is only the chord of 60°, so that angles above 60° do not appear. To construct an angle of more than 60°, first set off 60° on the circle drawn by means of the radius, and take the chord of the remainder from the sector. We think that the sector might be usefully copied in this respect on the common scales: giving all the length which the proposed scale will allow, to the chord of 60°, instead of that of 90°.

3. A line of *sines*, the radius of which is the sine of 90°. Thus, to find the upright side of a right-angled triangle having an hypothenuse of 3·41 inches, and an angle of 32°, open the sector until 90° and 90° on the counterpart lines of sines are 3·41 inches apart; then the distance from 32° to 32° on the same lines will be the side required.

4. A line of *secants*, usually extending to about 75°, the radius of course being the secant of 0°. This scale is blank from O to 0°.

5. A first line of *tangents*, from 0° to 45°, the radius being the tangent of 45°, or the whole length of the rule.

6. A second line of tangents, on a smaller scale, beginning at 45° and proceeding to about 75°, the radius being the tangent of 45°, or the distance from O to the beginning of the scale.

7. A line of equal parts for operations answering to finding a fourth proportional to three numbers. Thus to find a fourth proportional to 36, 47, and 53, make 36 and 36 on the counterpart scales fall as far apart as from O to 47; then the distance from 53 to 53 on the same scales, measured on the scale, will show the fourth proportional.

To write on the applications of the sector would be to make a treatise on graphical trigonometry: one instance may suffice. It is required to calculate the formula

$$76 \times \frac{\sin. 59°}{\sin. 38°}$$

On the counterpart lines of sines make 38° and 38° (by opening the sector) fall as far apart as from O to 59° on the same scale; then the distance from 76 to 76 on the counterpart lines of equal parts will show, on that line of equal parts, the numerical value of the result required. Or make 38° and 38° on the counterpart lines of sines fall as far apart as from O to 76 on the line of equal parts: then the distance from 59° to 59° on the counterpart lines of sines will show the result required on the scale of equal parts.

The sector becomes an incorrect instrument, comparatively, when a great opening is required, and also when the result is much greater than the data from which it is produced. So much accuracy of construction is necessary, that those to whom the instrument is often really useful (not many, we suspect) should rather procure the larger ones, which are manufactured by the best instrument-makers, than be content with the six-inch lines which are found in the common cases of instruments. The sector is an instrument which requires much more care than the common scale, and in the use of which expertness can be gained by nothing but practice. Each scale is a pair of parallel lines with cross divisions; and it is important to note that the compasses must be applied to the inner of the parallel lines in every case. Also when the compasses are in the hand, with one point laid on one of the scales, the other scale being about to be moved to bring the other point of the compass on the right division of the counterpart scale, take care to hold the compasses only by that leg which is laid down on the scale.

SECTOR, ZENITH. [ZENITH SECTOR.]

SECULAR, a name given to those variations in the planetary motions which are of long duration, so that their periods are better expressed in centuries than years.

SEDATIVES are agents which produce a direct depression of the action of the vascular system, with little sensible evacuation. They differ from narcotics, inasmuch as their depressing effects are not preceded by any obvious excitement or increased action of the heart and arteries. Whether they act primarily on the heart itself, or secondarily by a previous influence on the nervous system, is not clearly ascertained. Some, such as the infusion of tobacco, and hydrocyanic acid, appear to destroy completely the sensibility of the heart, so that it no longer responds to the stimulus of the blood; but how this effect results is altogether unknown. Oxalic acid, when the dose is large, seems also to paralyse the heart; while in less quantities it operates differently. [OXALIC ACID.] The peculiar mode of action of the articles entitled to be considered as pure sedatives has been detailed under the respective heads of DIGITALIS, HYDROCYANIC ACID, NICOTIANA, &c., and need not be repeated here. The medical employment of these formidable agents should never be had recourse to without competent authority and superintendence; but as many cases of poisoning result from their accidental or criminal administration, it is needful to observe that the greatest promptness is requisite in the administration of appropriate remedies. Vital stimulants, such as ammonia and brandy, are the best; and electricity or galvanism may be resorted to after the others.

Sulphuretted hydrogen, when breathed, injected into a vein of the rectum, or even applied to the skin, acts as a sedative, and in a small quantity can occasion death. It is largely disengaged from many decomposing substances, such as exist in stagnant pools, ditches, drains, and cesspools. Proximity to these produce effects more or less serious according to the intensity of the gas. Even one of its compounds, hydro-sulphuret of ammonia, is a potent sedative. Cold, when extreme, likewise acts as a sedative, but its mode of action has been already explained under BATHING. Chloroform and other anæsthetics may be considered sedatives of the nerves of sensation.

SEDILIA, in ecclesiastical architecture, the seats on the south side of the chancel, near the high altar, in Roman Catholic churches, in which the officiating priest and his attendant ministers sit during a portion of the performance of high mass. In many of our old collegiate and parish churches the sedilia still remain. The few that are extant of Norman date belong to the middle or latter half of the 12th century. In Pointed Gothic of every period they are frequent, and are almost always made a very ornamental feature. Usually they are recessed in the wall, like niches, and covered with canopies, which in some instances are lofty and much ornamented, resembling tabernacle work: but sometimes the sedilia are quite plain, little more in fact than stone benches. Commonly the sedilia are three in number, divided from each other by slender pillars, and gradated, that nearest the altar (intended for the priest) being the highest; but they are met with of varying numbers—from one to five—and all level, or with only the priest's seat raised above the others.

SEDITION (from the Latin *seditio*). It is stated that in many of the old English common law writers treason is sometimes expressed by the term Sedition; and that when law proceedings were in Latin, *seditio* was the technical word used in indictments for treason, till it was superseded by the word *proditio*.

Sedition does not appear to be very exactly defined. It is stated to comprehend contemptuous, indecent, or malicious observations upon the crown or government, whether made in words only, or in writing, or by tokens (which last term must comprehend pictures or drawings), calculated to lower the sovereign in the opinion of the subjects or to weaken his government. All these offences fall short of treason; but they are considered crimes at common law, and punishable by fine and imprisonment.

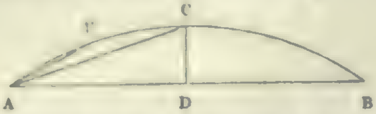
There are also statutes against particular acts of sedition, such as seditious libels. [LAW, CRIMINAL.] There are also various acts against societies established for seditious and treasonable purposes, and against seditious meetings and assemblies.

The Roman sense of *seditio* (*sed* or *se*, and *itio*, a going apart, a separation) is properly a disunion among the citizens, a riot, or turbulent assemblage of people for the purpose of accomplishing some object by violence or causing fear. It was included among other forbidden acts in the Lex Julia de Majestate. ('Dig.,' 48, tit. 4.) It is often used in connection with "tumultus" and "turba," and the three terms seem to have the same signification.

(Rein, *Römisches Criminalrecht*, p. 522.)

SEDUCTION. [PARENT AND CHILD.]

SEGMENT (part cut off), a term which, in its general sense, needs no explanation. It is, in mensuration, most frequently applied to the part cut off from a circle by a chord, and the measurement of this segment of a circle is the only point for which reference is likely to be made to the word. Let A B be the segment of a circle, and C and D the middle points of its arc and chord. The segment A C B is easily expressed by the angle which the arc subtends at the centre: if this angle (measured in the theoretical units [ANGLE]) be θ, and the radius r, the number of square units in the segment is



$$\frac{r^2}{2}(\theta-\text{sin.}\ \theta).$$

But when a segment is actually to be measured in practice, it usually happens that the radius is not given, and the circle is too large to measure it conveniently. In that case the middle point C must be found, and A B and A C must be measured, as also C D. This being done, the length of the arc A B can be found with great exactness from the formula "one third of the excess of eight times A C over A B, or $\frac{1}{3}$ (8 A C − A B)." This formula errs only about one foot out of 80 (always giving the arc a little too small) in a whole semicircle, and the error diminishes nearly as the fourth power of the arc; thus at half a semicircle the error is about one foot out of $2^4 \times 80$, or 1280 feet; at one-third of a semicircle it is only about one foot out of $3^4 \times 80$, or 6480 feet, and so on. Another formula of the same sort, but so close to the truth that no measurements could ever be taken in practice sufficiently exact to make its inaccuracy appreciable, is the following: find E the middle point of A C, and measure A E; then the arc is very nearly (but a little less than)

$$\frac{\text{AB}+256\ \text{AE}-40\ \text{AC}}{45}.$$

The error here is less than one foot out of 390 on the whole circle, and diminishes with the sixth power of the arc.

Taking the arc from one or other of these methods, the area of the segment is then to be found as follows:—Determine R, the radius, from $\text{AC}^2 \div 2\ \text{CD}$, and compute

$$\frac{\text{R}\times\text{Arc}-\text{AD}\,(\text{R}-\text{CD})}{2},$$

which gives the area required. This formula may be reduced to

$$\frac{\frac{2}{3}\,\text{AC}^2\,(2\ \text{AC}+\text{AD})-\text{AD}^3}{\text{CD}}.$$

Thus (to take an instance of Bonnycastle's) if AD = 12, AC = 13, whence CD = 5 (all feet), we have for the area of the segment

$$\frac{\frac{2}{3}\times169\times38-1728}{5}=82{\cdot}533 \text{ square feet.}$$

Another approximate rule is (giving somewhat too little)

$$\frac{\text{CD}\,(12\ \text{AD}+8\ \text{AC})}{15},$$

which is more exact than the preceding. The error is only one per cent. when the segment is a semicircle, and it diminishes with the seventh power of the subtended angle nearly.

It answers well enough for rough purposes, and particularly when the segment is small, to consider the arc of the circle as being part of a parabola, and to take two-thirds of the rectangle under A B and C D for the area.

SEIGNORAGE. [CURRENCY.]

SEIGNORY. [TENURE.]

SEISIN is a term properly applied to estates of freehold only, so that a man is said to be *seised* of an estate of inheritance or for life, and to be *possessed* of a chattel interest, such as a term of years. This distinction does not appear to have existed in the time of Bracton; at least he uses the two words as identical in meaning ("possessio sive seisina multiplex est,' lib. ii., fol. 38).

The seisin of the tenant of a freehold is the legal possession of the land. It is actual seisin, called seisin in deed, when he has corporeal possession of the land, or, as Bracton expresses it, "corporalis rei detentio: corporis et anima cum iuris adminiculo concurrente." It is seisin in law when lands have descended to a person, but he has not yet actually entered into possession of them, and no person has usurped the possession. When an estate of inheritance is divided into several estates, as for instance an estate for life, and a remainder or reversion in fee, the tenant in possession has the actual seisin of the lands; but the persons in remainder or reversion have also seisin of their respective estates.

In the conveyance of land by feoffment, which is now, however, almost unknown, the delivery of the possession, or livery of seisin, as it is termed, is the efficient part of the conveyance. [FEOFFMENT.]

Seisin in deed is obtained by actually entering into lands, and an entry into part in the name of the whole is sufficient; by the receipt of rents or profits; and by the actual entry of a lessee to whom the lands are demised by a person who is entitled to but has not obtained actual possession.

Seisin may also be acquired under the Statute of Uses, 27 Hen. VIII., which enacts that when any person shall be seised of any lands *to the use*, &c., of another, by reason of any bargain, sale, feoffment, &c., the person having the use, &c., shall thenceforth have the lawful seisin, &c., of the lands in the same quality, manner, and form as he had before in the use.

A disseisin supposes a prior seisin in another, and a seisin by the disseisor which terminates such prior seisin. To constitute a disseisin, it was necessary that the disseisor should not have a right of entry; the disseisee should not voluntarily give up his seisin; and that the disseisor should make himself the tenant of the land, or in other words, should put himself, with respect to the lord, in the same situation as the person disseised. "But," it is well remarked (Co. Litt., 266 b, Butler's note), "how this substitution was effected, it is difficult, perhaps impossible, now to discover. From what we know of the feudal law, it does not appear how a disseisin could be effected without the consent or connivance of the lord; yet we find that the relationship of lord and tenant remained after the disseisin. Thus after the disseisin the lord might release the rent and services to the disseisee; might avow upon him; and if he died, his heir within age, the lord was entitled to the wardship of the heir." But the doctrine of disseisin is in many respects very obscure, and at present of very little practical importance.

SEISMOLOGY, from *σεισμος*, an earthquake (that is, a movement like the shaking of a sieve), and *λόγος*, a discourse, the science of earthquakes; and SEISMOMETRY, from the same, and *μετρέω*, to measure, the science of the mensuration of all the phenomena of earthquakes which can be expressed in numbers, or by their relation to the co-ordinates of space. The origin of these new departments of science has been stated in the article EARTHQUAKES, in which the physical definition of an earthquake was also given, agreeably to the researches of Mr. Robert Mallet. We now proceed to state some of the elements of seismology, and the nomenclature applied to them, premising that the basis of this is formed by the adjectives *seismal* and *seismic*, both signifying what has relation to an earthquake. An earthquake being the transit of a wave of elastic compression through the earth, there are three elements of this earthquake-wave, namely, the velocity of transit, the velocity of the wave-particle (or wave itself [WAVE]), and the direction of motion at each point of the *seismic area*, or tract on the earth's surface within which the earthquake is felt. From the last element may be determined, 1st, the point upon the earth's surface vertically over the centre of effort, or focal point, whence the earthquake impulse was delivered; and 2nd, the depth below the surface (or rather sea-level) of the focal point itself. The line passing through both these points is the *seismic vertical*. The wave starts from the focal point with one normal and two transversal vibrations, and may be imagined transferred outwards, in all directions, in concentric spherical shells, whose volume at the same phase of the wave is constant. The shock reaches the surface directly above the focal point vertically; but, for all points around that, it emerges with angles becoming more and more nearly horizontal as the distance measured on the surface increases. The intersecting circle of any one shell with the surface, which is that of simultaneous shock, is the *coseismal line*, or crest of the earth-wave: circular if in a homogeneous medium, more or less distorted if in a heterogeneous one (such as constitutes the various geological formations of the earth's crust), but always a closed curve. The *meizoseismal area* is that in which the shock is experienced in the greatest degree, and *isoseismal areas* are those in which it is felt at the same time. A *seismic region* is a tract of the earth's surface, the earthquakes of which have some community of origin, manifested by their simultaneous occurrence. *Seismic energy* is the total amount of force exerted in earthquakes at a given period, or in a given space, or with relation to any other element of the subject. *A chrono-seismic curve*, laid down from the records of earthquakes, the ordinate of which is that of epoch, and the abscissa that of *seismic intensity* (in this case the force of a given earthquake), expresses the progression of seismic energy in time.

Every object displaced by an earthquake shock is in fact a *seismometer*, and in the selection and arrangement of suitable objects for such displacement, so as to give the required evidence of the velocity and directions of the motion, consists the practical science of seismometry. For particulars of the construction and principles of complete self-registering seismometers, we must refer to Mr. Mallet's Fourth Report to the British Association; but we proceed to notice some extemporaneous seismometers with which important observations may be made, under circumstances in which fixed instruments cannot be appealed to. The elements necessary to be recorded, Mr. Mallet states, in his article 'On Observation of Earthquake Phenomena,' in the third edition of the 'Admiralty Manual of Scientific Inquiry,' are such as will enable us to calculate, in order to obtain finally the actual elements of the wave itself, as stated above—1, the direction in azimuth of the wave's motion upon the earth's surface, and also its direction of emergence at the points of observation. 2, Its velocity of transit upon the surface. 3, Its dimensions and form—that is, its amplitude and altitude.

If a common barometer be moved a few inches up and down by the hand, the column of mercury will be found to oscillate up and down in the tube in directions opposite to the motions of the instrument, the range of the mercury depending upon the velocity and range of motion of the whole instrument. A barometer fixed to the earth, therefore, if we could unceasingly watch it, would give the means of measuring the vertical element of the shock-wave; and if we could lay it down horizontally, it would do the same for the amplitude, or horizontal element. This we cannot do; but the same principle may be put into use by having a few pounds of mercury and some glass tubes bent into the form of the letter L, sealed close at one end, and open at the other; together with some common barometer tubes, having the open end turned up like an inverted syphon. The instruments to be constructed of these are of the nature of fluid pendulums. They are superior to common solid pendulums, where the dimensions of the shocks are small; but where these are great and very violent, heavy solid suspended pendulums will be found more applicable. The length of the seconds pendulum for the latitude of Greenwich will always be desirable.

Mr. Mallet thus describes a solid pendulum, of easy construction, which will answer several important purposes of seismometry. "Fix a heavy ball, such as a four-pound shot, at one end of an elastic stick, whose direction passes through the centre of gravity of the ball: a stout rattan will do. Fix the stick vertically in a socket in a heavy block of wood or stone, and adjust the length above the block as near as may be to that of the seconds pendulum for Greenwich. Prepare a hoop of wood, or other convenient material, of about 8 inches diameter; bore four smooth holes through the hoop in the plane of its circle, and at points 90° distant from each other: adjust through each of these a smooth round rod of wood (an uncut pencil will do well), and make them, by greasing, &c., slide freely, but with slight friction, through the holes. Secure the hoop horizontally at the level of the centre of the ball by struts from the block, and the ball being in the middle of the hoop, slide in the four rods through the hoop until just in contact with the ball. It is now obvious that a shock, causing the ball to oscillate in any direction, will move one or more of the rods through the holes in the hoop, and that they will remain to mark the amount of oscillation.

"A similar apparatus, with the pendulum-rod secured horizontally (wedged into the face of a stout low wall, for example), will give the vertical element of the wave. Two of these should be arranged, one north and south, the other east and west. One objection to this and all apparatus upon the same principle is, that as the centre of elastic effort of the pendulum-rod never can be insured perfectly in the plane passing through the centre of gravity of the ball, for every possible plane of vibration, so an impulse in a single plane produces a conical vibration of the pendulum, and hence the ball deranges the position, more or less, of the index rods which are out of the true direction of shock. Moving the apparatus by hand, and a little practice in observation of its action, will, however, soon enable a pretty accurate conclusion as to the true line of shock to be deduced from it."

The observer must record minutely the dimensions and other conditions of such apparatus, to enable calculations as to the wave of scientific value to be made from his observations of the range of either fluid or solid pendulums. "A common bowl partly filled with a viscid fluid, such as molasses, which, on being thrown by oscillation up the side of the bowl, shall leave a trace of the outline of its surface, has been often proposed as a seismometer. This method has many objections; it can only give a rude approximation to the direction of the horizontal element; but as it is easily used, should never be neglected as a check on other instruments. A common cylindrical wooden tub, with the sides rubbed with dry chalk and then carefully half filled with water or dye stuff, would probably be the best modification."

Such instruments and contrivances as those now described, suffice to give the direction of transit of the earth-wave, and its dimensions. Its rate of progress or transit over the shaken country remains to be observed; and wherever it may be possible to connect three or more such instruments, at moderately distant stations, say from fifteen to thirty miles apart, by galvanic telegraph wires, so as to register at one point the moment of time at which each instrument was affected, the best and most complete ascertainment of transit rate may be expected. On the entire subject of extemporaneous seismometry, we must again refer the intending observer to Mr. Mallet's article in the 'Admiralty Manual' before referred to.

Since the publication of the article EARTHQUAKES, Mr. Mallet has applied the method of investigating their phenomena, announced in his reports published in those of the British Association, to the earthquake of December 16, 1857, noticed in that article, the greatest that has occurred in Italy since that of 1783; having personally examined its effects. He has incorporated the results in an elaborate report read to the Royal Society on the 24th of May, 1860, and of which an abstract is given in vol. x. of the Society's 'Proceedings,' p. 486–494, the report itself being reserved for the 'Philosophical Transactions.'

From that abstract the following particulars are derived, being the result of the first exact investigation of the phenomena of a great earthquake. It was felt over nearly the whole of the Italian peninsula, south of Terracina in the States of the Church, near the Neapolitan frontier, about 56 miles south-east from Rome, and of Gargano, on the Adriatic. Its area of greatest destruction, or meizoseismal area, within which nearly all the towns were wholly demolished, was an oval, whose major axis was in a direction north-west and south-east nearly, and about twenty-five geographical miles in length by ten in width. The first isoseismal area beyond this, within which buildings were everywhere more or less prostrated and people killed, is within an oval of about sixty geographical miles by thirty-five; the second isoseismal is also an oval within which buildings were everywhere fissured, but few prostrated, and few or no lives lost. The third isoseismal embraces a greatly enlarged area, within which the earthquake was everywhere perceived by the unassisted senses, but did not produce injury. A fourth isoseismal was partially traced, within which the shock was capable of being perceived by instrumental means, and which probably reached beyond Rome to the northward.

The seismic vertical, Mr. Mallet determined from the independent and concurrent evidence of above seventy separate wave-paths, was close to the village of Caggiano, near the eastern extremity of the valley of the Salaris. The depth of the focal point below the sea-level, that is, the *mean* focal depth was found to be about 5¾ geographical miles. From all the information, observed and calculated, it was deduced that the *focal-cavity*, within which the seismic energy originated, was a curved lamellar cavity, or fissure, of about three geographical miles in depth by nine in length, with an inclined vertical section, and a mean focal depth (or depth of its central point of surface) of 5¾ miles below the level of the sea, as just stated. The probable horizontal form of the cavity, when laid down upon a map, co-ordinates with the existing lines of dislocation of the country in a remarkable manner. Mr. Mallet, it may here be remarked, assumes the force that acted within this cavity to have been due to steam of high tension, either suddenly developed or suddenly admitted into a fissure rapidly enlarged by rending.

The most trustworthy of the observations of time correspond with considerable exactness, and give a velocity of transit of the wave of shock upon the surface, of between 700 and 800 feet per second. Strictly speaking this is the velocity at which the *wave-form* was propagated from point to point. The velocity of the wave itself, or of the *wave-particle*, was in round numbers between 13 and 14 feet per second in the direction of the wave-path. Mr. Mallet points out a remarkable relation between this velocity and that recorded for the earthquake of Riobamba, as the greatest whose effects have been observed. The height due to the velocity of this wave is to the altitude of Vesuvius as that due to the velocity recorded of the Riobamba wave is to the mean height of the volcanic shafts of the Andes, and more especially to the height of the volcanic vents nearest to Riobamba. [VOLCANOS.] The wave of shock, of course, decays in relation to superficial distance from the seismic vertical. The amplitude of the wave slowly and slightly increases, and its velocity decreases. In the case of the Italian earthquake under investigation, the lowest velocity at nearly 30 miles from the seismic vertical was still about 11⅙ feet per second. The total modifying effects of this earthquake on the earth's surface were insignificant. No great sea wave accompanied it; nor was such possible, the focal point being inland. Mr. Mallet examined with care more than 150 miles of sea-coast, as well as river-courses, for evidence of any permanent elevation of land having taken place concurrently with the earthquake, but found none. This is an important point, because geologists and travellers have often ascribed elevations of the land to earthquakes, or to a succession of earthquake-shocks directed upon the same spot; but "earthquakes," Mr. M. observes, "cannot produce elevations, although the latter have been known to have taken place about the same time as earthquakes, and in the same region." . . . . "The functions of elevation and depression," of an earthquake, "are limited solely to the sudden rise and as immediate fall, of that limited portion of the surface through which the great wave is actually passing momentarily."

The works and memoirs cited in this and in the article EARTHQUAKE, will make the student acquainted with the entire available literature on the subject of earthquakes.

SELECT VESTRY. [VESTRY.]

SELENALDINE. [THIALDINE.]

SELENE (Σελήνη), the Moon, was worshipped as a goddess by the ancient Greeks. She is generally represented as the sister of Helios, or the Sun; sometimes as his daughter, and occasionally as his wife, and the mother of the four Seasons. She is also said to have had children by Zeus and several others. The story of Endymion, whom she caused to fall into a perpetual sleep that she might unseen gaze upon his beauty and enjoy his embraces, is well known from the use made of it by the poets. By him she is said to have been the mother of fifty daughters. She was believed to drive her chariot through the heavens during the night. (Hom., 'Hymn.,' xxxii. 7.) Her chariot is usually represented in ancient works of art drawn by two horses, whereas that of Apollo was drawn by four. She is only distinguished from Artemis by being more fully draped. She is frequently represented in bas-reliefs on sarcophagi, hovering in the air over the sleeping Endymion. In course of time the attributes of Selene were given to Artemis, and the latter was represented as the goddess of the moon; but these deities were originally distinct. [Artemis.]

SELENETHYL. [Selenium.]

SELENIC ACID. [Selenium.]

SELENIOUS ACID. [Selenium.]

SELENITE. [Calcium. *Sulphuric Acid and Lime.*]

SELENIUM (Se) a nonmetallic, solid, elementary body, discovered in 1818 by Berzelius in the iron pyrites of Fahlun; the sulphur procured from which was used at Gripsholm in the manufacture of sulphuric acid. In the latter a deposit was formed of a red colour, which, on account of the peculiar odour that it emitted, was supposed, though erroneously, to contain tellurium, the origin of which name suggested that of *selenium*, from Σελήνη, the moon, for the new substance. The discoverer considered it a metal, but it is now classed with the nonmetallic elements.

Selenium has been found hitherto only in small quantity; it occurs in the pyrites of Anglesey, and probably in that of many other places: sulphide of selenium has been detected among the volcanic products of the Lipari Isles; and in the Harz it has been met with, combined with lead, silver, and some other metals.

Magnus extracts selenium from the native sulphide by treating it with binoxide of manganese, by the oxygen of which the sulphur is converted into sulphurous acid, which escapes in the gaseous form, while the selenium either sublimes in its pure state or as selenious acid.

Selenium is a brown somewhat transclucent solid when in mass. It is inodorous and insipid, moderately hard, may be readily scratched with a knife, is brittle as glass, and easily reduced to powder. Its fracture is conchoidal. Its sp. gr. varies from 4·30 to 4·8, on account of the cavities which it frequently contains. It is a bad conductor of heat, and a non-conductor of electricity. It softens at 212°, and may be drawn out into fine threads, which are transparent, and of a red colour by transmitted light. When heated rather higher, it becomes fluid, and boils at 650°, emitting a vapour, which is inodorous, and of a deep yellow colour; this in close vessels condenses in dark globules of a metallic lustre, or of a cinnabar-red colour, according as the space in which it collects is small or large. Water does not dissolve selenium; it is however soluble in the fat oils and melted wax, but not in the volatile oils. The equivalent of selenium is 39·75.

Oxygen and Selenium combine in three different proportions, forming oxide of selenium, selenious acid, and selenic acid.

Oxide of Selenium (SeO) may be formed by heating the selenium in a limited quantity of atmospheric air, and by washing the product to separate the selenious acid formed with it. It emits a very strong smell resembling that of decayed horse-radish, so that 1-50th of a grain of selenium is sufficient when burnt to scent a room of considerable size, and this is a characteristic property of selenium. Oxide of selenium is gaseous, colourless, very slightly soluble in water, and quite devoid of acid properties.

Selenious acid (SeO_2) may be prepared by passing a current of oxygen gas over heated selenium; but it is more conveniently obtained by digesting selenium in nitric acid or nitro-hydrochloric acid till dissolved, and then evaporating the solution to dryness.

This acid is colourless, and when strongly heated sublimes, and condenses unchanged in the form of acicular crystals, which possess distinctly marked acid properties. It attracts moisture from the air and is consequently very soluble in water; a hot saturated solution yields crystals on cooling; it is also soluble in alcohol, and has when heated an acrid odour. It forms salts with bases, which are called *Selenites.*

Many substances which have strong affinity for oxygen decompose selenious acid; this is the case with sulphurous acid and phosphorous acid, and when the former is added to a solution of selenious acid, a red powder is precipitated, which is pure selenium, and sulphuric acid is at the same time formed. An alkaline sulphate produces a similar effect; hydrosulphuric acid is also decomposed by and decomposes selenious acid, and a yellow compound is formed and precipitated, which is sulphide of selenium.

Selenic Acid ($HO.SeO_3$) may be prepared by fusing selenium, a selenide, or selenite, with nitrate of soda. The seleniate of soda obtained is to be decomposed by nitrate of lead, and the insoluble seleniate of lead precipitated is to be decomposed by a current of hydrosulphuric acid, which throws down the lead as a sulphide. The selenic acid remains in solution, with some excess of hydrosulphuric acid, which is to be expelled by ebullition.

Selenic acid is liquid, colourless, inodorous, of an oleaginous consistence, and very acid; it attracts moisture from the air, and always retains about 12·4 per cent. of water, which cannot be expelled without decomposing the acid. It may be heated to 536° without decomposition, but at 554° it is rapidly converted into oxygen and selenious acid. When concentrated at a temperature of 329°, its sp. gr. is 2·524, and it gradually increases up to the temperature of 545°, when it becomes 2·625. When mixed with water, much heat is evolved. Its salts are called *Seleniates.* Zinc and iron are dissolved by this acid with the evolution of hydrogen gas, and copper with the formation of selenious acid.

Seleniate of soda ($NaO, SeO_3 + 10$ aq.) occurs in large crystals like those of Glauber's salt. *Seleniates of lime* ($CaO, SeO_3 + 2$aq.) and of *nickel* ($NiO, SeO_3 + 6$aq.) resembles the corresponding sulphates. *Seleniate of Cadmium* ($CdO, SeO_3 + 2$aq) differs both in composition and crystalline form from the sulphate of cadmium, the crystals also lose an equivalent of water on being heated to 212° Fahr.

Hydrogen and Selenium (HSe) unite to form hydroselenic acid or seleniuretted hydrogen. It is easily obtained by the action of diluted sulphuric acid upon selenide of potassium, or of iron. This gas is colourless, has a disagreeable odour, and so powerfully irritates the membrane lining the nose as to excite symptoms of catarrh, and destroy the sense of smelling for some hours. Water readily dissolves this gas: the solution is at first colourless, but after a time it acquires a reddish hue; it gives a brown stain to the skin, and reddens litmus paper. When exposed to the atmosphere it is decomposed, its hydrogen being absorbed by oxygen, and the selenium is deposited. It decomposes the solutions of many metallic salts, selenides of the metals being precipitated.

Chlorine and Selenium combine when the gas is passed over the selenium; heat is evolved, and a brown chloride is obtained, which is liquid; it is heavier than water, not very volatile, and by the action of water is eventually decomposed, and resolved into selenious and hydrochloric acids and selenium.

This *dichloride* (Se_2Cl) may be converted into a *bichloride* by exposure to excess of chlorine. It is a white solid compound which is volatilised when heated, and condenses in small crystals. It is decomposed by water.

Sulphur and Selenium (S_2Se). A definite compound of these is formed by passing hydrosulphuric acid gas into a solution of hydroselenic acid; the fluid assumes a yellow colour, becomes turbid, and a precipitate is formed, though but slowly, unless a little hydrochloric acid be added. When exposed to heat this disulphide of selenium becomes red and viscid, and at high temperatures may be distilled without decomposing.

Phosphorus and Selenium combine when the selenium is dropped into melted phosphorus; the product is a red substance, but it does not appear that any definite compound of these bodies is formed.

Selenethyl or *selenium-ethyl.* [Ethyl, *selenide of ethyl.*]

Selenium forms *selenides* with most of the metals, and the selenide of lead is one of the most abundant of the native compounds which occur in the Hartz. [Lead, in Nat. Hist. Div.]

The characteristic properties of selenium are those of tinging the flame of the blowpipe of a light blue colour, and emitting an acrid vapour, when heated in the air, which has the peculiar smell of decayed horse-radish.

SELENIURETTED HYDROGEN. [Selenium.]

SELF-REGISTERING INSTRUMENTS. In the determination of scientific data, it is of the utmost importance that the instruments of observation be as free from error as possible, or that the sources and amount of error be accurately known. It is further necessary that the means of observation be irreproachable, and, if possible, continuous. Where an instrument requires to have its indications recorded night and day, a large staff of observers is required, and they are liable to error, even when carefully trained to their work. [Equation, Personal.] The magnetic instruments at the Greenwich Observatory were formerly observed every two hours; but the results were of course liable to error, and occasionally the magnetic variations were too rapid and transient to be recorded. Hence attempts—and many of them successful ones—have been made from time to time to make instruments of observation record their own results. We have seen under Anemometer the contrivances for registering the direction and pressure of the wind, together with the amount of rain; and under Barometer some of the mechanical arrangements are stated for making that instrument self-registering. The maximum and minimum thermometers in ordinary use will be described under Thermometer. Our object in this place is briefly to notice the vast improvement that has taken place of late years in consequence of the application of photography to the purposes of self-registration. A description of the apparatus employed for the self-registration of the changes in position of the declination magnet, of the horizontal force magnet, and of the vertical force magnet, will show the nature of the arrangements. A prepared photographic paper is wrapped round a cylinder, the axis of which is placed parallel to the direction of movement to be registered, and the cylinder is turned round at a uniform rate by clockwork. The light is supplied by a gas-lamp furnished with a copper chimney, in which is a small slit capable of adjustment by a screw. It is on the breadth of this slit that the breadth of the register-line depends. This light falls upon a concave speculum, which rests in a stirrup connected with the magnet to be observed, so as to partake of all its angular movements. The pencil of light is reflected from the mirror to a plano-convex lens, placed near to, and parallel with, the axis of the cylinder, which lens condenses the line of light to a definite spot of light on the paper. The source of light being fixed, it is evident that the movements of the spot of light will correspond with those of the magnet, to the right and left in a horizontal plane in the case of the declination magnet and horizontal force magnet, and up and down in a vertical plane in registering the movements of the vertical force magnet. Hence, as the cylinder is constantly being moved round by clockwork, there is traced upon the paper a curve of which the abscissa, measured in the direction of a line round the cylinder, is proportional to the time, while the ordinate, measured in the direction of the axis of the cylinder, is proportional to the movement of the magnet. A base-line, from which to measure the ordinates, is traced upon the paper by the action of a spot of light proceeding from another gas-lamp placed near the cylinder and passing through a slit fixed to the carrier of the cylinder.

In the photographic registration of the barometer, the instrument is arranged in the siphon form, and a float, resting on the surface of the mercury in the shorter limb, hangs in a notch on the short arm of a delicately poised lever. At the end of the long arm of this lever is an opaque screen containing a small aperture, through which a pencil of light passes. Now it is evident that, as this screen moves up and down with the oscillations of the mercury, a line will be traced on the photographic paper by the pencil of light transmitted by the screen. There is also an arrangement for tracing a base-line on the photographic paper. The cylinder carrying the sensitive paper is mounted on a turn-table, which is carried round by the hour-hand of a clock placed concentrically beneath it. The paper is covered by a second cylinder to prevent it from becoming dry, during the twenty-four hours that the apparatus remains in action. The cylinders are also covered with a blackened zinc case to prevent all light from falling on the paper, except that from the pencils which describe the register and the base line.

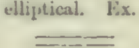
In the photographic registration of the thermometer and psychrometer, the bulbs of the instruments are freely exposed beneath a table on which is a revolving cylinder covered with sensitive paper, while the stems pass up through the table, and are placed between the cylinder and a source of light, which, by means of a cylindrical lens, falls on the stem of the thermometer in a narrow vertical line, and, passing through that part of the bore which is above the mercury, blackens the sensitive paper. The boundary between the affected and the unaffected parts of the paper indicates the position of the mercury in the stem of the instrument. Fine wires are placed across the slit through which the light passes, and coarser wires are attached to every tenth degree, as well as to the points 32°, 54°, 76°, and 98° Fahr. The shadows of these wires protect the portion of the paper on which they fall from the action of the light, so that the darkened surface of the paper is traversed by a series of parallel pale lines, and the relative positions of the broad and narrow lines show the temperature indicated by the register. The whole of the apparatus is protected by an outer wind- and water-tight zinc case.

SELINUNTINE MARBLES. [Sculpture.]

SEMAPHORE. [Telegraph.]

SEMIBENZIDAM. Synonymous with *Azophenylamine.* [Organic Bases.]

SEMIBREVE, a character in music, sometimes nearly circular in form, but more commonly elliptical. Ex.:

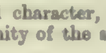


This is adopted as the measure-note in music; the other five characters that indicate duration, as minim, crotchet, &c., being considered as proportional parts of it.

SEMICOLON. [Punctuation.]

SEMINAPHTHALIDUM. [Naphthalic Group. *Nitronaphthylamine.*]

SEMIQUAVER, a musical character, formed of a crotchet with two hooks added at the extremity of the stem, and is in duration $\frac{1}{16}$ of a semibreve. Ex.:



SEMITIC LANGUAGES. [Aramæan, or Aramaic Language; Hebrew Language; Language.]

SEMITONE, an interval in music, whose ratio is 16 : 15, as C C♯.

SENATUS, according to the etymological meaning of the word, is "an assembly of elders," and this is the sense which the Roman writers attach to the earliest senate of Rome. The number of senators in the Greek republics, as well as at Rome, always bore a certain relation to the number of tribes of which the state was composed. Hence, as long as Attica was divided into four tribes, the number of senators was 400; and when Cleisthenes divided the country into ten tribes, he increased the number of senators to 500. As long as Rome only comprehended one tribe, the Latins of the city on the Palatine, their senate consisted of only 100 members. After the accession of a second tribe, the number of senators was raised to 200; and when a third tribe was united with them, the number of senators was increased to 300. Each of the three Roman tribes was divided into ten curiæ, and each curia into ten gentes, and the same number of decuries, containing, according to Göttling, parts of several gentes, and made for purposes of representation. At the head of each gens there was a decurio, who, according to Niebuhr, by virtue of this office was a senator, or a representative of his gens in the senate. But Walter ('Gesch. des Röm. Rechts,') justly observes that the age of a decurio, who was at the same time a military officer, and consequently must always have been a young man and able to bear arms, does not appear to be consistent with the age and duties of a senator. It is much more probable that each decury elected from its own body one by whom it was represented in the senate. Each curia was thus represented by ten senators, who were called a "decuria senatorum" (Liv., i. 7). At the head of this decuria senatorum was a curio, and the ten heads of the decuries, when the senate consisted of only 100 members, or ten decuries, were the "decem primi," from among whom the king chose one as princeps senatus. It appears that when the Ramnes and Tities became united, and the senate consisted of twenty decuries, the ten decuries of the Ramnes with their decem primi still retained for a time a kind of superiority over the Tities. (Dionys. Hal., ii.; Plut., 'Num.,' 3.) The senators representing the Ramnes gave their votes first, and the princeps senatus was chosen from among them alone. But the first two tribes must soon have been placed on a footing of equality, so that some of the decem primi, as well as the princeps senatus, might belong to either of the tribes. (Dionys., *l. c.*) After the union of the third tribe, the senators representing the first two are supposed by Niebuhr to be the "patres majorum gentium," and those representing the third to be the "patres minorum gentium." Göttling ('Gesch. d. Röm. Staatsv.) on the other hand considers the "patres minorum gentium" to have been the noble plebeians whom Tarquinius Priscus admitted into the three old tribes, and who, in consequence of this, became eligible to the senate. (Cic., 'De Rep.,' ii. 20.) The patres minorum gentium had at first, as Niebuhr (ii., p. 114) supposes, no right to speak in the senate, but merely voted by *going over* to either party; and he therefore conceives that they were the "senatores pedarii." (Gellius, iii. 18; Dionys., vii., p. 453.) This name of senatores pedarii might in subsequent times, when all the senators had equal rights, be applied to all senators indiscriminately, as it was their general custom to vote by discessio, or a division. All writers agree that Tarquinius Priscus raised the number of senators to 300, but the manner in which this was effected is stated differently. Cicero (*l. c.*) says that the king doubled the existing number of senators (which would accordingly have been 150), while others (Liv., i. 35; Dionys., iii., p. 199) state that he merely added 100 senators to the existing number of 200. Niebuhr ingeniously reconciles these two statements by the supposition that before the time of Tarquinius Priscus some of the gentes of the first two tribes had become extinct, though it does not follow that the number of the extinct gentes amounted exactly to fifty. But if, as we have supposed, the senators were not elected by each gens, but by a decuria, Niebuhr's supposition must fall to the ground, as it cannot be conceived how decuries could become extinct, as they might be formed in such a manner that one large gens would comprehend several decuries, while smaller ones united in forming one decury, and thus were always able to make up a certain number of decuries. The statement of Cicero appears to rest upon a misconception. (Göttling, p. 228.) Servius Tullius did not introduce any change in the composition of the senate, but in the reign of the last king, Tarquinius Superbus, the number of senators is said to have become greatly diminished, as many of them were put to death, and others were sent into exile. These vacancies however were filled up immediately after the establishment of the republic by electing into the senate the principal plebeians of the equestrian order. Livy (ii. 1) ascribes this completion to L. Junius Brutus; Dionysius (v., p. 287), Plutarch ('Popl.,' 11), and Festus (*s. v.* "qui patres"), to Valerius Publicola. The number of these new plebeian senators is said to have been 164, but this is utterly incompatible with the subsequent history of Rome. The new plebeian senators were called Conscripti, in contradistinction to the patrician senators, or patres; hence the mode of addressing the whole senate "patres conscripti," that is, "patres et conscripti." The word patres, although in later times used to designate senators in general, was originally another name for patricians. (Liv., ii. 1; Fest., *s. v.* "adlecti;" Niebuhr, i., p. 327, &c.) The number of 300 senators henceforth remained unaltered for several centuries. C. Gracchus was the first who attempted an alteration. Livy ('Epit.,' lib. 60) says that he wished to increase the senate by adding 600 equites, but this seems a mistake, and the reading is probably corrupt. Plutarch ('C. Gracch.,' 5, &c.) says that he added 300 equites to the 300 senators, and transferred to this body the Judicia (publica). All the other writers who mention these events (see the passages in Göttling, p. 237, note 3) do not allude to an increase in the number of senators, but merely state that he transferred the Judicia to the equites. A similar attempt was made by the tribune Livius Drusus. (Appian, 'Civil.,' i. 35.) Sulla added 300 equites to the senate, and thus increased its number to 600. [Sulla, in Biog. Div.] Four hundred senators were after this time present in a case when many were absent. (Cic. 'ad Att.', i. 14.) Julius Cæsar increased the number of senators to 900, and elected men of the lowest rank into the senate. (Dion Cas., liii. 47.) This mode of filling up vacancies or increasing the number of senators with freedmen and common soldiers was continued after the death of Cæsar, and at one time there were more than 1000 senators. (Suet., 'Aug.,' 35.) Augustus again reduced the number to 600. (Dion Cass., liv. 14.) Respecting the number of senators during the empire, we possess no direct information. During the latter period of the empire the number of senators appears to have become greatly diminished.

The senators were from the earliest times elected for life. Their name indicates that originally they were men of advanced age, but the exact age at which a man might become a senator during the kingly period is not mentioned. During the latter centuries of the republic, however, the age seems to have been fixed by some Lex Annalis, as the ætas senatoria is frequently mentioned. But as a quæstor after the year of his office might be made a senator, and as the legitimate age for the quæstorship was twenty-five years, we have reason to believe that a person who had attained the age of twenty-six might be elected a senator. It might, however, be inferred from Polybius (vi. 17) that this was not the case till a person had completed his twenty-seventh year. As regards the election of persons into the senate during the kingly period, Livy (i. 8) and Festus (*s. v.* 'Præteriti Senatores') state that it was a privilege of the kings. Dionysius (ii., p. 85), though he involves himself in difficulties by supposing that the three tribes were already united when the senate consisted of only 100 members, is undoubtedly right in stating that the senators were not appointed by the kings. (Niebuhr, i. p. 338.) The senators were elected by the decuries, and thus were real representatives of the curies, or a select body of the populus. The plebeians, who were afterwards admitted into the senate by Tarquinius Priscus, and after the banishment of the kings, must either have been incorporated with the patrician gentes, or their number must have been very small, for the first instance of a plebeian senator at Rome is Sp. Maelius, in 439 B.C.; and a second is P. Licinius Calvus, in 400 B.C., although the latter may have held the office of quæstor, and so have got admission into the senate. Niebuhr (i. p. 527, &c.) thinks that long before the institution of the censorship there must have been a time when the senators were chosen by the curies, and not by the subdivisions of the curies, and that each curia elected ten senators. He founds this supposition upon the Lex ovinia tribunicia mentioned by Festus (*s. v.* 'Præteriti Senatores'). But as regards the time, Niebuhr is manifestly wrong, which he himself seems to have felt afterwards (ii., p. 403, note 885); for the Lex Ovinia refers to the censors, whom it directed to elect into the senate "optimum quemque curiatim." (Compare Göttling, p. 345, &c.; Walter, 'Gesch. d. Röm. R,' p. 100, &c.) During the early period of the republic, the right of electing persons into the senate belonged to the consuls, dictator, and military tribunes. But all the curule magistracies, as well as the quæstorship, conferred upon those persons who had held them the right of being elected into the senate. (Liv., xxii. 49, "unde in Senatum legi deberent.") The quæstorship conferred this right probably from the earliest times, as it did in the time of Sulla [QUÆSTOR], and this circumstance explains why the patricians opposed the eligibility of the plebeians to the quæstorship. After the establishment of the censorship, the election of persons into the senate was wholly in the hands of the censors. All curule magistrates, that is, consuls, prætors, curule ædiles, and censors, had by virtue of their office a seat in the senate, and might speak on any subject. After their office was over they retained this right, but without being real senators. Now vacancies in the senate were filled up at every lustrum, and it was only on this occasion that the censors might elect those ex-magistrates into the senate whose conduct was unblemished. Hence we have to distinguish between two kinds of senators, real senators (senatores), and such as were allowed "dicere sententiam in senatu." (Fest. *s. v.* 'Senatores.') The old decem primi senatus are no longer mentioned. The honour of princeps senatus, which during the kingly period had been combined with the office of custos urbis, and had been granted by the kings for life, was afterwards united with the office of prætor urbanus, or with that of a military tribune (Liv., vi. 6), and only lasted for one year. After the establishment of the censorship, this honour was conferred by the censors, and at first upon the eldest among the living ex-censors; but afterwards upon any one whom the censors thought most worthy. (Liv., xxvii. 11.) If the censors thought a person who had held a curule office unworthy of being a senator, they passed over him ("præteribant:" Fest., *s. v.* 'Præteriti'); but this seems to have seldom occurred with persons who had held a curule office. (Liv., xxxiv. 44; xxxviii. 28.) The plebeians as an order never obtained the right of being eligible as senators; but as soon as the great offices of the republic became accessible to the plebeians, their claims to the dignity of senator could not be disputed. As, therefore, the quæstorship, consulship, censorship, and prætorship, were one after the other thrown open to the plebeians, their numbers in the senate likewise continued to increase. At last (perhaps in the year 131 B.C.; Walter, p. 165, note 156), even the tribunes of the people, after having before acquired the right to convoke the senate and to take part in its deliberations, gained by the Plebiscitum Atinium the rights of real senators. (Gellius, xiv. 8.) On certain occasions a dictator was created for the purpose of electing new members into the senate. (Liv., xxiii. 22, &c.) M. Fabius Buteo, in 216 B.C., not only elected such men as had held curule offices, but also such as had been plebeian ædiles, tribunes, quæstors, and persons who had distinguished themselves as soldiers. The senate, which at first had been the representative of the populus, thus gradually became the real representative of the people; for although the censors or a dictator were the electors, yet, either by custom or by law, they always elected such men as had held offices given by the people, so that it was in fact the people who elected the members of the senate, and the Roman senators themselves viewed their dignity as from the people. (Cic. 'pro Sext.,' 65; 'c. Verr.,' iv. 11; 'pro Cluent.,' 56.) This also accounts for the fact that the members of the great colleges of priests, with the exception of the flamen dialis (Liv., xxvii. 8), had no seats in the senate; and for the same reason it was a disputed point whether the præfectus urbi should have a vote in the senate (Gellius, xiv. 8), for in the colleges of priests vacancies were filled up by co-optatio of the members themselves, and the præfectus urbi was appointed by the consuls, and none of them derived their power from the people. In the time of Cicero, however, this appears to have been altered, for we find that pontiffs might at the same time be senators. (Cic. 'ad. Att.,' iv. 2.) Notwithstanding all this, however, the senate, down to the end of the republic, preserved in a great measure its original character; it remained an aristocratic body.

During the republic we do not hear that any property qualification was required for a senator (Plin., 'Hist. Nat.,' xiv. 1), though the senators must generally have belonged to the wealthiest classes. There is indeed a passage in Livy (xxiv. 11) from which it has been inferred that previous to the second Punic war a senatorial census was instituted (Niebuhr, iii., p. 406); but the words of Livy are too vague to admit of such an inference, and probably refer only to the fact that senators were among the wealthiest Romans, and were consequently able to make greater sacrifices to the republic than other persons. Göttling (p. 346) concludes from Cicero ('ad Fam.,' xiii. 5) that Cæsar was the first who instituted a senatorial census, but the passage of Cicero is even less conclusive than that of Livy. The first to whom the introduction of a senatorial census is expressly ascribed is Augustus. He first fixed it at 400,000 sesterces, but afterwards increased it to 800,000, and at last to 1,200,000 sesterces. (Suet., 'Aug.,' 41; Dion Cass., liv. 17, 26, 30; lv. 13.) If a senator lost or spent so much of his property as to fall short of the senatorial census, he was obliged to withdraw from the senate, unless the emperor connived, or supplied the deficiency. (Tacit., 'Annal.,' ii. 48; xii. 52; xv. 28; 'Hist.,' iv. 42; Suet., 'Aug.,' 41; 'Tiber.,' 47; Dion Cass., lx. 11.) The senatorial age was fixed by Augustus at twenty-five years (Dion Cass., lii. 20), and the names of the senators were entered on a list called 'Album Senatorium.' (Tacit., 'Annal.', iv. 42; Dion Cass., liv. 13; lv. 3.) Augustus reduced, as we have seen, the number of senators to 600, and cleared their body from the unworthy persons who had been admitted before his time. He also improved the senate by electing into it the most distinguished citizens of municipia and colonies, and even provincials. (Tacit., 'Annal.' iii. 55; xi. 25; Suet., 'Vespas.,' 9.) Such senators of course resided at Rome, and, with the exception of those who belonged to Sicily or Gallia Narbonnensis, they were not allowed to visit their former homes without a special permission of the emperor. (Tacit., 'Annal.,' xii. 23; Dion Cass., lii. 42; lx. 25.) At a later period these foreign senators were required to purchase a certain amount of landed property in Italy. (Plin., 'Epist.,' vi. 19.) The emperors also assumed the right of convoking the regular as well as extraordinary meetings of the senate (Dion Cass. liii. 1; liv. 3), although the consuls, prætors, and tribunes continued to enjoy the same privilege. (Tacit. 'Hist.,' iv. 39; Dion Cass., lvi. 47; lix. 24.)

Senators were never allowed to carry on any mercantile business. About the commencement of the second Punic war, however, some senators seem to have entered into mercantile speculations; and a law was passed, notwithstanding the opposition of the senate, that no senator should be allowed to possess a ship of more than 300 amphoræ in tonnage (Liv., xxi. 63), this being thought sufficiently large to convey to Rome the produce of their possessions abroad (comp. Cic. 'c. Verr.,' v. 18); from which passage it is clear that this law was not always observed. No one moreover could be elected senator whose parents were not free men by birth (ingenui). The first violation of this custom was attempted by the censor Appius Claudius Cæcus, who elected into the senate the sons of freedmen. (Liv., ix. 29 and 46; Aurel. Vict., 'De Vir. Illustr.,' 34.) But this election was considered illegal. Towards the close of the republic such proceedings appear to have been rather common. (Dion Cass., xl. 63; iii. 47; Horat.. 'Sat.,' i. 6, 21.) If a senator was struck from the lists of senators by the censors, he was not disqualified for any of the great state offices, but he might still obtain them, and thus find his way back to the senate. (Cic. 'pro Cluent.,' 46; Dion Cass., xxxviii., 30; xliii. 52; comp. "Nota" in 'Dict. of Greek and Rom. Antiq.')

The regular meetings of the senate (*senatus legitimus*) during the republic were held on the calends, nones, and ides of every month. (Cic. 'ad Quint. Frat.,' ii. 13.) Extraordinary meetings (*senatus indictus* or *edictus*) might be convoked on any day, provided it was not a dies comitialis, or a dies ater. Augustus decreed that a senatus legitimus should only be held twice every month, on the calends and on the ides; that during the months of September and October, only a small number of senators, drawn by lot, should attend; and that their attendance should be sufficient to enable the body to transact business. (Suet., 'Aug.,' 35; Dion Cass., lv. 3.) What number of senators was necessary in order to constitute a legal meeting is uncertain: on some occasions, however, as we see from the senatus consultum de Bacchanalibus (Liv., xxxix. 18), a decree could not be made unless there were one hundred senators present. Sometimes also it was found necessary to enforce the attendance by a multa, or a pignoris captio. (Cic., 'Philip.,' i. 5.) Augustus increased the severity of the law in this respect. (Dion Cass., liv. 18; lv. 3; lx. 11.) At first he required the presence of four hundred members to constitute a full assembly; but he afterwards reduced this number; and at a later period, the presence of seventy, or even fewer senators, was sufficient. (Lamprid., 'Alex. Sev.,' 16.)

The places of meeting for the senate (curiæ or senacula) were always templa, that is, places consecrated by the augurs; and there were originally three of them: 1, the temple of Concordia, between the Capitol and the Forum; 2, a place near the Porta Capena; and 3, a place near the temple of Bellona, outside of the city. (Fest., *s. v.* 'Senacula.') Subsequently, however, meetings of the senate were held in a great many other places. The place near the temple of Bellona was principally used for the purpose of giving audience to generals who returned from their campaigns, and were desirous to obtain a triumph; also to receive foreign ambassadors, especially such as were sent by an enemy, and were not allowed to enter the city. Towards the close of the republic, it was decreed that during the whole month of February the senate should give audience to foreign ambassadors on all days on which a senate could be held, and that no other business should be transacted in the senate until the affairs of the foreign ambassadors were settled. (Cic. 'ad Quint. Frat.,' ii. 13; 'ad Fam.,' i. 4.)

In the earliest times of Rome, the right of convoking the senate belonged to the kings or their vicegerents, and they also introduced the subjects for discussion. The princeps senatus, or custos urbis, put the question. The patres majorum gentium voted first, and the patres minorum gentium last. (Cic., 'De Rep.,' ii. 20.) During the republic the senate might be convoked by the consuls, the dictator, the prætor, the tribunes of the people, the interrex, or the præfectus urbi: the decemvirs, military tribunes, and the triumviri rei publicæ constituendæ, likewise exercised this right; but the persons who intended to convoke the senate generally offered sacrifices to the gods and consulted the auspices. (Gellius, xiv. 7.) The assembled senators appear to have sat in a regular and fixed order: first, the Princeps senatus; then the Consulares, Censorii, Prætorii, Ædilicii, Tribunicii; and lastly, the Quæstorii. In this succession they also gave their votes. (Cic., 'Philip.', v. 17; xiii. 14; 'Ad. Att.', xii. 21.) The majority always decided. This mode of voting remained the same during the empire. (Plin., 'Epist.', viii. 14; ix. 13; Tacit., 'Annal.', iii. 22; xi. 5.) The business was conducted as follows: the magistrate who had convoked the senate was always the president, and he laid before the assembly the subjects for discussion, opening the business with the words, "Quod bonum, faustum, felix, fortunatum sit; referimus ad vos, patres conscripti." After the subject of discussion was explained, the president asked the senators for their opinion in the order in which they sat. (Liv., i. 32; ix. 8.) If the consules designati were present, they had the precedence even of the princeps senatus. (Sallust., 'Cat.', 50; Cic. 'Philip.', v. 13.) If any of the members dissented from the measure proposed, he might express his opinion freely, or propose an amendment to it. After the discussions were over, the president called upon the members to vote; and the majority, which decided the question, was ascertained either by numeratio or discessio. A sitting of the senate was, generally speaking, not continued after sun-set; but in unexpected or very urgent cases the business was carried on by candle-light, and even till after midnight. Augustus introduced the custom that every senator, before he took his seat, should offer incense and a libation to the god in whose temple the meeting was held. (Suet., 'Aug.', 35.) During the time of the empire one of the consuls seems always to have presided in the senate, and the emperors only when they were consuls (Plin., 'Epist.', ii. 11); but by virtue of their tribunician power, they might at any session introduce any subject they pleased (Dion Cass., liii. 32), and subsequently this privilege was granted to them by an especial decree (jus relationis). (Vopisc., 'Prob.', 12; J. Capitol., 'Pertin.', 5; 'M. Antonin.', 6; Lamprid., 'Alex. Sev.', 1.) The measures or propositions made by an emperor were introduced in the form of written orations (orationes principum), and read in the senate by one of his quæstors. (Suet., 'Aug.', 65; Tit., 6, Tacit., 'Annal.', xvi. 27.) The manner of conducting the business was on the whole the same as in the time of the republic. But when magistrates were elected in the senate, the votes were given by ballot. (Plin., 'Epist.', iii. 20; xi. 5.) Previous to the time of Cæsar the transactions of the senate were not kept or preserved in any regular way. (Plut., 'Cat. Min.', 23.) Cæsar was the first who ordained that all the transactions of the senate (acta senatus) should be kept and made public. (Suet., 'Cæs.', 20.) These transactions were written under the superintendence of one of the senators (called "ab actis," or "à cura actorum"), by scribes appointed for the purpose. (Tacit., 'Annal.', v. 4, &c.; Spart., 'Hadr.', 3.) In case the business of the senate was carried on in secret, the senators themselves officiated as clerks. (Jul. Capitol., 'Gord.', 12.)

Down to the end of the republic the senate of Rome partook more or less of the character of a body representing the people: it was, as Dionysius says (v., p. 331, vi. p. 408), the head and soul of the whole republic, or the concentrated intelligence and wisdom of the whole nation. It is chiefly to the consistency, wisdom, and energy with which the senate acted during a long period that Rome was indebted for her greatness and her success.

During the kingly period the kings acted according to the determinations of the senate, and the kings had only the executive. The subjects on which the senate decided before they came before the people, comprehended the whole internal administration of the state, legislation, finance, and war. On the death of a king the senate proposed the new candidate to the comitia by means of the interrex. (Liv., i. 17.) At the establishment of the republic no change appears to have been made in the power and authority of the senate. The senate and the people had the sovereign power. At first all measures, whether relating to the administration or legislation, originated with and were prepared by the senate; but this power was afterwards considerably diminished by the attacks of the tribunes of the people. In many cases the original state of things became reversed, inasmuch as laws might originate with the people, and only require the sanction of the senate; or might have the power of law even without this sanction. [Tribunus.] A still more formidable blow was inflicted upon the power of the senate when the tribunes obtained the right of invalidating its acts by their intercessio. [Tribunus.] The power which the senate exercised during the republic, when the tribunes did not intercede, may be comprised under the following heads:—

1. The senate had the control of the public treasury (ærarium) ('Polyb.', vi. 13); the accounts of all the revenues were laid before the senate, and no part of the public money could be expended without their consent. Hence no consul or magistrate could raise an army, or keep it at the expense of the state, unless he was authorised by the senate. [Scipio, in Biog. Div.]

2. Crimes committed in Italy, such as treason, conspiracies, poisoning, and murder, belonged to the cognizance of the senate; moreover, if any private individuals or any of the allied towns of Italy had disputes among themselves, if they had done anything deserving punishment, or if they required assistance or a garrison, all this was within the power of the senate. (Polyb., vi. 11; comp. Liv., xxx. 26.) In cases, however, where a judicial sentence was required, the senate appointed a person, but did not pronounce sentence itself. (Cic., 'De Off.', i. 10; Val. Max., vii. 3, 4.)

3. All ambassadors sent from Rome, and all commissioners charged with the regulation of the affairs of a newly conquered province, were nominated by the senate, and the ambassadors themselves were in many cases members of the senate. All foreign ambassadors communicated with the Roman senate. (Polyb., *l. c.*; and Livy, in numerous passages.) Treaties concluded with foreign nations by a Roman general required the sanction of the senate.

4. The senate assigned to the consuls and prætors their respective provinces [Provincia], and the senate might at the end of a year propose the prolongation of their imperium.

5. The senate decreed all public thanksgivings (supplicationes) for victories obtained by the generals of the republic; and the senate alone could confer on a victorious general the honour of a triumph or of an ovatio. (Liv., v. 23; Cic., 'Philip.', xiv. 5.)

6. The senate in times of great danger could delegate unlimited power to the consuls; and this was done by the formula, "videant consules nequid respublica detrimenti capiat." The senate had also the supreme superintendence in all matters of religion, and decided whether the worship of new gods was to be adopted or not. [Serapis.]

During the empire the senate lost its former character, for the emperors became the sovereign, and the senate was a subordinate power, and little more than a high court of justice. Respecting the provinces of the senate, see Provincia. The senators, however, were always looked upon as persons of the highest rank. Vacancies were filled by the emperor at discretion, chiefly with equites, whence the equites are called seminarium senatus. (Lamprid., 'Alex. Sev.', 19; Joseph., 'Antiq. Jud.', xix. 1.) Constantine established a second senate at Byzantium, and the emperor Julian conferred upon it the privileges which were enjoyed by the senators of Rome. (Zosimus, iii. 11.) Both senates were still sometimes addressed by the emperors in a imperial oration concerning matters of legislation, and each of the senates still continued to be a high court of justice, to which the emperors referred important criminal cases. The senatorial dignity was now obtained either by descent, by the favour of the emperor, or by virtue of having held some office at the imperial court. The senators enjoyed many distinctions, but their burdens were exceedingly heavy, for they had to pay a peculiar tax (follis) upon their landed property, to give public games, and magnificent presents to the emperors, and, in times of need, large donations to the people. The emperors, therefore, contrived to elect into the senate the wealthiest persons from all parts of the empire. (Walter, 'Gesch. d. Röm. Rechts.')

From the time of Diocletian the senate was only a shadow of its former state, but it was still the highest object of the ambition of the wealthy Romans.

It now remains to mention some of the external insignia and the privileges of the Roman senators.

1. The *latus clavus*, or *tunica laticlavia*, or a tunica with a broad purple stripe, which was not sewed to it, but woven in it.

2. A kind of short boots with the letter C on the top of the foot. This C is generally interpreted to mean centum, and to refer to the original number of a hundred (centum) senators.

3. A particular place (orchestra) in the theatres and amphitheatres.

This was first assigned to the senate by Scipio Africanus Major, B.C. 194 (Liv. xxxiv. 54; comp. Cic. 'pro Cluent.', 47.) In the reign of Claudius they obtained the same distinction at the games in the Circus. (Suet., 'Claud.', 21; Dion Cass., lx. 7.)

4. On the day when sacrifices were offered to Jupiter, the senators had a public feast on the Capitol, and this distinction, which no one else had, was called jus publice epulandi. (Suet., 'Aug.', 35; Gellius, xii. 8.)

5. The jus liberæ legationis, that is, senators, when allowed to travel abroad, had a right to demand from the inhabitants of the towns or countries through which they travelled, all that was necessary for their support or accommodation. Towards the end of the republic this right was much abused, wherefore Cicero obtained the passing a law which limited the time during which a senator might be absent and enjoy the jus liberæ legationis to one year: Cæsar, however, extended it to five.

SENECA INDIANS. [North American Indians.]

SENEGUIN. [Saponin.]

SENESCHAL, a word rarely used except by persons who affect a kind of refinement of style which they think is attained by using words of exotic growth rather than words the natural growth of their own soil, the meaning being precisely that which is represented by the word "steward," and this when the word is applied to officers so designated of the greatest eminence; the lord high-steward of England or of Scotland being the proper phrase for that great officer, and not lord-high-seneschal. But the functions of the officer called steward in Britain corresponding with those of the officer called seneschal abroad, and especially in France, when the word appears in Latin, it is represented by *senescallus*, writs running "Senescallo Hospitii Regis," &c., when addressed to the steward. In poetry and romance-writing it is sometimes used for a principal officer in the household of distinguished persons, when it is thought that the word steward would be too familiar, and suggest an officer whose duties are of an inferior class to those of the seneschal.

SENNA is prepared from several species of *Cassia* [Cassia, in Nat. Hist. Div.], of which the *acutifolia*, grown in Egypt, Sennaar, and Abyssinia, and shipped from Alexandria, is considered the best. The leaflets, leaf stalks, and pods are frequently present in the senna used in medicine. The pulp of *C. Fistula*, called also *Cathartocarpus Fistula*, consists chiefly of sugar and gum, with some other principles, and is a mild laxative. It accordingly enters into the composition of the confection of cassia, and the confection of senna or lenitive electuary. These are pleasant-tasted but rather bulky purgatives for children. They are not much used, and the pulp of cassia is chiefly employed to form what is termed essence of coffee. This, when prepared from pulp which has not been kept too long, is mildly cathartic, and a very proper article of diet for persons subject to habitual constipation.

Senna contains a peculiar principle called *cathartine*, with a fat oil, and a little volatile oil, a colouring principle, mucilage, and malate and tartrate of lime, chlorophylle, &c.

The active or purging principle is yielded to water, both cold and warm, and to alcohol. If the infusion be made with cold water, it never gripes: this method is now much employed to form the concentrated infusions supplied by wholesale chemists and druggists to country practitioners. It requires that the water should stand twenty-four hours on the leaves, which should be kept down with a heavy weight, and the air excluded as thoroughly as possible. The tincture is almost an unnecessary form, while the powder is objectionable from its bulk and disagreeable taste. Various articles, especially aromatics, are occasionally added to infusions to correct its griping tendencies, or increase its purgative power. The confection is an example of such combinations in a solid state. A carefully prepared extract keeps well, retains the odour and virtue for years, and may be given in moderate-sized boluses or pills.

SENSIBILITY, an aptitude for receiving impressions of the senses. This is its physiological meaning, as designating that faculty of the senses whereby things external are made to act upon us. That peculiar fineness of organisation which renders a man alive to the impressions of physical objects, has, by a natural metaphor, become the expression of that peculiarity of mental organisation which renders the mind alive to impressions of moral objects, such as pity for the distress of others, admiration of heroic courage or patient endurance, &c.; and thus a person with a keen sense of grandeur, sublimity, nobility, beauty, or pathos in nature or art, is said to possess great sensibility. It is this moral aspect of sensibility which in all people creates the love of poetry and fiction, and when possessed in a high degree creates the poet himself.

A singular but suggestive theory of universal sensibility was propounded by Campanella in his work 'De Sensu Rerum;' but its daring assumptions, however consonant to a poetical temperament, require greater accuracy, larger data, and more logical deductions, before this hypothesis can have any weight with exact thinkers; and in fact it has gained few converts.

SENTENCE. [Judgment; Organon.]

SENTINEL, or **SENTRY** (from *sentire*, to look or perceive), is a term now applied to an infantry soldier when placed on guard before the palace of a royal personage, or before some other public building; also when guarding the ramparts of a fortress, or, on an army being in the field, when he is stationed on the exterior of the line of outposts. [Piquet.]

SEPARATE PROPERTY. By the common law of England the husband acquired by the marriage a freehold interest in, and a right to dispose of, the rents and profits, during the joint lives of himself and his wife, of all the estates of inheritance of which she was at that time seised, or might become seised during the coverture, as well as a right to an estate for his own life as tenant by the curtesy in the event of his surviving his wife and there having been issue of the marriage. By the common law, also, marriage was an absolute gift to the husband of all the goods and personal chattels of which the wife was actually possessed at that time or might become possessed during the coverture, and it gave him a right to dispose of her chattels real and of such of her choses in action as he should have reduced into possession during the same period. There was no mode by which the wife could take or enjoy any estate or property absolutely independent of her husband.

In process of time, however, limitations of both real and personal property to the separate use of the wife were established in courts of equity, and the validity of them has been recognised even in courts of law. It was at first considered necessary that property which was to be enjoyed by a married woman for her separate use should be vested in trustees for her, but it has since been settled that where either real or personal property is given to the separate use of a married woman, without any appointment of trustees, the husband shall be considered a trustee for her. This principle applies *à fortiori* when the property is expressly given to the husband for the separate use of his wife. In the same manner the agreement in writing between the husband and wife before marriage, that his wife shall be entitled to any specific property for her separate use, converts him into a trustee for her as to that property; and if the subject of agreement be real estate, and be such as to give the wife a power of disposition, the agreement will be binding on her heir, and make him a trustee for her appointee. The consideration of what is or is not a valid settlement of property by the husband to the separate use of his wife as against creditors and purchasers, belongs to the general doctrine of marriage settlements. [Settlement.]

Many questions have arisen upon the construction of particular instruments as to what words are necessary to raise a trust for the separate use of the wife. The result of the cases upon this point may be stated to be, that when, from the nature of the transaction and the context of the instrument, the intention to limit the property to the wife for her separate use is clear, whatever may be the particular expressions used, that intention will be carried into effect; but that the courts of equity will not interfere to deprive the husband of the interest which he would otherwise take in his wife's property upon doubtful inferences or ambiguous expressions. It has sometimes been doubted whether property could be limited in trust for a woman, whether married or sole at the time, so as to enure to her separate use in the event of a second or future marriage; but the recent decisions upon this point, in accordance with the general practice of conveyancers, leave no room now to doubt their validity. The intention to extend the limitation to future covertures must, however, be clearly declared; for if the apparent object be to protect the fund against the particular husband, a declaration that the trust shall continue during the life of the woman will not extend it to a future marriage.

Separate estate may be acquired not only in lands and personalty, but in the profits of trade carried on by the wife on her separate account, in consequence either of express agreement between her and her husband before marriage, or his subsequent permission. Upon the general principles applicable to marriage settlements, the agreement in the former case will be good against creditors; in the latter against the husband only. In such cases the stock in trade and property required for carrying on the business are usually vested in trustees for the wife, who is considered at law as their agent, and should carry on all business transactions in their names. But if no trustees should have been appointed, the rule of equity before stated will apply, and the husband will be bound by his agreement, that all his wife's earnings in trade shall be her separate property and at her own disposal.

When personal property, whether in possession or reversion, is settled to the separate use of a married woman, she may dispose of it and the produce of it as a feme sole to the full extent of her interest, though no particular power be given by the instrument of settlement. But a mere limitation of real estate in fee to the sole and separate use of a married woman, though it enables the wife to dispose of the rents and profits as a feme sole, gives her no power of disposition over the estate beyond what she has by the common law. The gift to the separate use may be accompanied by an express power of appointment by deed or will. The rules of law relating to the formal execution of such powers, and the cases in which defective execution will be supplied, are the same as those which are applicable to the execution of powers in general. [Uses.]

It is not necessary in all cases of settlement of personal property to the separate use of a married woman, accompanied with a power of appointment, that she should appoint in terms of the power. Upon this point the following distinctions are established:—1. When there is an express limitation of an estate for life in the fund to the wife, with a power to appoint the principal after her death, the wife can dispose of the capital only by an execution of the power, which may be immediate, if the power authorise an appointment by deed; but if it require the appointment to be made by will only, then it cannot take effect till after her death. This is equally true whether the limitation in default of appointment be to a stranger, to the next of kin, or to the executors and administrators of the wife. 2. When the wife takes the absolute interest in the property, although it should be limited to her in the form of a power, she may dispose of it under her general power, and without regard to the ceremonies prescribed by the instrument. Under the second head are included all the cases in which the trust for the wife appears to be of the principal and not of the interest only, and the effect of such a limitation will not be controlled by the introduction of any subsequent provisions as to the mode of payment of the interest or otherwise.

The foregoing observations with respect to the powers of disposition by a married woman of the capital of a fund given generally to her separate use, are equally applicable to the cases where the interest or rent of property only, or income of whatever kind, is the subject of the settlement. If no particular power to dispose be given, she may do so under that general power which, as before mentioned, a married woman possesses over her separate personal estate, and even where a particular mode of disposition is prescribed in the instrument of settlement, she will not, it seems, be bound to follow it.

If the wife, having a general power of disposition of her separate property, permit her husband during his life to receive and apply her separate estate as his own, a gift from her will in general be presumed, and she will not be allowed at his death to charge his estate with the amount so received.

If the wife, having power to dispose absolutely of her separate property, die without making any disposition of it, the quality of separate property, it seems, ceases at her death, and the surviving husband is entitled to the fund. If the property consist either of chattels real or personal in possession, he will be entitled to them without administration; but if of choses in action, he must take out administration to her estate.

In some cases where a married woman, having an absolute power of appointment over a fund, has executed it, a bill has been filed, in order that the consent in court of the wife to the disposition might be taken; and this practice occasioned a doubt whether it was not necessary that the wife's consent in court should be obtained, especially in cases where the appointment was in favour of the husband. But unquestionably the appointment is valid without any such consent, and the presence of the wife in court, whether the appointment be to her husband or to strangers, is entirely unnecessary.

It was at one time doubted whether the wife's general power of alienation of her separate estate could be restrained by the expressed intention of the settlor, such restraint being thought repugnant to the interest which she had in the property; but the power of the settlor to impose it is now established by undoubted authority. The intention to impose this restraint will not however be inferred in the absence of express words to that effect. If the gift be to a woman unmarried at the time when it takes effect, a clause against anticipation, that is, a clause which prohibits or limits the power of alienation, though inserted expressly in contemplation of a future marriage, is inoperative, as it would be in the case of a man, to prevent alienation while she continues sole; and if the gift be to a woman married at the time, the property becomes absolutely disposable by her upon the expiration of the coverture. It has also been much questioned whether, in the cases supposed, the property, if not alienated by the woman while discovert, would be subject to the settlement to her separate use and to the prohibition against anticipation during any future coverture or covertures. The question has been decided in the affirmative, and is now well settled. (Tullet *v.* Armstrong, 4 M. & C., 390.)

It has been stated that if a married woman has property settled to her separate use, without any restraint on alienation, she may dispose of it as a feme sole, either with or without consideration; but it seems to be now determined (though there are conflicting decisions on the point among the older authorities), that, in order to affect her separate estate, she must show an intention to charge it, and that it is not liable to answer generally the demands of creditors. It is not very clearly determined in what cases and from what circumstances the intention to charge the separate estate will be presumed. It seems to be established that the separate estate of a married woman is liable to debts for which she has given a written security or acknowledgment, such as a bond or promissory note. The extent to which a woman's separate property may be subjected to the demands of creditors claiming under parol agreements has not been determined. If the separate property consists of land, it will of course not be liable; because, by the Statute of Frauds (29 Car. II., § 3), no agreements can affect lands unless they are in writing and signed by the party to be charged; but if of personalty, it is probable that an express parol agreement that her separate property should be charged with the payment of a debt, or even perhaps a tacit agreement to be implied from the circumstances, as when the wife is living separate from her husband, would be held binding on the property.

It has sometimes been considered that upon the principle of the general liability of the separate property to debts, after the death of the wife, in the administration of it among creditors, all ought to come in *pari passu*, as in other cases of the administration of equitable assets; but the later authorities seem to show that the separate property of a feme covert is not subject at her death to any such general liability, and from this it would appear to follow that the creditors whose debts are charged upon it ought, as specific incumbrancers, to be paid according to their priorities.

The wife, in equity, as at law, can incur no personal responsibility by her engagements as to her separate property, and is liable only to the extent of that property in the hands of her trustees; but in suits respecting her separate estate she is treated in all respects as a feme sole, and is personally answerable for contempt in not obeying the orders of the court. In such suits, if she is a plaintiff, she must sue by her next friend, and not with her husband, who however should be made a defendant to the wife's bill: and if she is a defendant, she must be served personally with process in the cause. She must answer by her next friend separately from her husband, who ought however to be made a party to the bill.

The savings and earnings of a wife may become her separate property *at law*, and she may deal therewith as a feme sole, either where an order has been made to that effect under the statute 20 & 21 Vict. c. 85, or a judicial separation has been obtained by the wife.

(Bright, *On Husband and Wife;* and Lord St. Leonards, *On Powers.*)

SEPARATION A MENSA ET THORO. [DIVORCE.]

SEPARATION, JUDICIAL. Until the statute 20 & 21 Vict. c. 85, divorces *a vinculo*, which put an end to the marriage altogether, were only obtainable by a special act of parliament, which the legislature would not pass in favour of a husband until after a sentence of separation *a mensâ et thoro* in the ecclesiastical court, and would not pass at all if his conduct had not been free from reproach. [DIVORCE.] Either of the spouses could always however obtain, on the ground of adultery, cruelty, and certain other causes, a divorce *a mensâ et thoro*.

The remedy now given in such cases by the Court for Divorce and Matrimonial Causes is termed a *judicial separation*. This, like a divorce *a mensâ et thoro*, does not dissolve the marriage; it does not bar the wife of her dower, for instance; it effects only such a separation of the parties as leaves it open to them to come together again. But it relieves the husband from all liability for his wife; and it confers on the wife the right of having and disposing of her own property and earnings, as freely as if she were a feme sole.

This kind of separation may be obtained on the ground of adultery or cruelty, or desertion without cause for two years or upwards; but unlike a decree for a divorce, which is absolute and irreversible, a sentence of judicial separation may be reversed at any time afterwards, if obtained in the absence of the defendant, on its appearing that there was reasonable ground for the alleged desertion.

In cases either of divorce or judicial separation, the Court may, if it shall think fit, order that the husband shall secure to the wife such sum as it shall deem reasonable. The allowance which may thus be made to a woman for her support out of the husband's estate, is to be settled at the discretion of the court on consideration of all the circumstances of the case, and to be proportioned to the rank of the parties.

SEPIRINE. A resinous alkaloid, found along with *bebirine* in the bark of the *bebeeru* tree of British Guiana.

SEPOY, or SIPOY, the name of the native soldier in the East Indies, probably from *sipahi*, the Persian word for soldier, though Bishop Heber derives the word from "sip," the bow and arrow, which were originally in almost universal use by the native soldiers of India in offensive warfare. Those Bhiels and Kholees who are employed in Guzerat in the service of the police and in protecting gentlemen's houses and gardens are also called sepoys, and with more propriety, as they still use the bow and arrow. The native soldiers in the pay of the British government now form a large army, well trained in European discipline. Though the men of some of the regiments composed of men of the highest caste are said to have been of a greater average size than the Europeans, the generality are somewhat smaller than European soldiers, but brave, hardy, and active, capable of undergoing much fatigue and of sustaining great privations. To the attachment and bravery of this army, which was not doubted till rudely shaken by the mutiny of the Bengal army in 1857, Great Britain is chiefly indebted for the possession of her Indian empire, and the security of her sovereignty over a territory vastly more extensive than her own, and separated from her by the distance of nearly half the globe.

Bombay was the first possession which the English obtained in India, but the establishment on that island was for a long time on a very limited scale, and required nothing more than its own garrison and a few companies of native troops, who were peons, subject to little control, to no fixed military law, and who used their native weapons in preference to muskets. The French were the first to set the example of employing natives regularly instructed in European discipline. Labourdonnais, in the siege of Madras in 1746, had 400 sepoys well armed and well trained, besides 400 disciplined negroes from Madagascar, in addition to his European soldiers. A corps of 100 sepoys from Bombay and 400 from Tellichery are mentioned as having joined the army of Madras in 1747, but these were probably only peons and bands of undisciplined natives hired for the occasion. In 1748 a small corps of natives was raised in the neighbourhood of Madras, and trained and disciplined by Mr. Haliburton, a lieutenant. From 1748 to 1766 the sepoys were in separate companies of 100 each, commanded by subadars, or native captains, though under the superintendence of Europeans. In 1766 the companies were formed into battalions of 1000 men each, commanded by European officers, under whom the subadars still retained their rank and influence. In 1796 two battalions were made to constitute a regiment, which continued to be the form till about 1820, since which time each regiment has been made to consist of two battalions of 500 men each. This description of force was adopted also in Bombay and Madras, and continued to increase. In 1856, just before the mutiny of the Bengal army, the native army was composed of 240,120 men, forming,—

5 Troops of horse artillery.
18 Companies of artillery.
22 Regiments of regular cavalry.
155 Regiments of regular infantry.
23 Regiments of irregular cavalry.
30 Regiments of irregular infantry.
5 Contingent brigades of all arms.
1 Native legion.

The native army, which, with the whole of the Company's troops, were in 1858 transferred with the government of India and placed under the crown, having been in great part destroyed by the mutiny of the Bengal army, is now greatly reduced, and is being reorganised and placed on the footing of irregulars. In irregular regiments the number of European officers is very small, the men receive high pay, and provide their own horses, forage, &c.

SEPTEMBER, the ninth month, as the year is now divided by European nations. It consists of 30 days. Etymologically the name is improper, being a Latin term formed of *septem*, seven, and the termination *ber*; and the same impropriety belongs to October, November, and December. The Roman year originally commenced in March; and the English names of the months, which are all Latin terms, appear to have been given to them by the lawyers, whose writings were formerly in Latin, and who supposed the year to commence in March, on which supposition the names are right, September being the seventh, October the eighth, &c., when March is the first. The legal year in England was not made to commence on the 1st of January till the alteration of the style in 1752.

Other appellations were given to this month under some of the Roman emperors. The Saxons called it *Gerstmonath*, or barley-month, gerst being the original Saxon name for barley, which was the chief grain cultivated by the Saxons, and commonly harvested in this month.

SEPTUAGESIMA. [Sexagesima.]

SEPTUAGINT, or THE ALEXANDRINE VERSION OF THE OLD TESTAMENT, the most ancient translation of any part of the Scriptures. It is in the Greek language. The account of its origin is given in a letter ascribed to Aristeas, an officer at the court of Ptolemy Philadelphus, and repeated by Josephus ('Antiq.,' xii., c. 2) and Eusebius 'Præpar.', Evang. viii., c. 2–5. [Aristeas, in Biog. Div.]

Philo says that the Septuagint was translated from the Chaldaic, by which he means the Hebrew Scriptures as they existed after the Captivity. But from certain points of resemblance between the Septuagint and the Samaritan Pentateuch, many eminent critics have concluded that the former was translated from the latter, and not from the Hebrew. It is, however, quite incredible that, if this had been the case, the Septuagint should have been, as it was, universally received by the Jews.

The character of the version varies greatly. By far the best part is the version of the Pentateuch, which was evidently made by a man well acquainted with both Hebrew and Greek. Next in value is the book of Proverbs, which is for the most part very accurate, and displays much poetical taste. The translation of Ecclesiastes is too literal. The books of Judges, Ruth, Samuel, and Kings appear to have been translated by the same author, and do not contain so many Hebraisms as other parts of the version. In the book of Job many interpolations are made in the narrative, and there are considerable omissions in the poetical parts. The book of Esther, and the Psalms and Prophets, appear to have been translated between 180 and 170 B.C., but in a very inferior manner: indeed a great part of the version of the Psalms is quite unintelligible. Jeremiah is the best translated of the prophets; next come Amos and Ezekiel. The version of Isaiah, which Lowth places 100 years later than that of the Pentateuch, is the worst of all, except that of Daniel, which differs so much from the Hebrew, that the early Christians rejected it altogether, and substituted the version by Theodotion in its place. The Septuagint contains also the apocryphal books of the Old Testament. [Apocrypha.]

The Septuagint was used not only by the Hellenistic Jews, but by all Jews who understood Greek; and even some of the Talmudists mention it with praise. It is constantly quoted by Josephus, and very frequently by the writers of the New Testament.

Soon after the Christian era, however, we find the opinion of the Jews respecting it very much altered, probably in consequence of the use made of it against them by the Christians. They went so far as to institute a solemn feast on the 8th of the month Thebet (December) to execrate the memory of its having been made, and afterwards a new version, that of Aquila, was made for the express purpose of superseding the use of the Septuagint in the synagogues. [Aquila, in Biog. Div.] The fathers of the Greek church always quote the Septuagint. All the early versions, except the Syriac, were made from it. And thus, through the Vulgate, it was used in the Latin as well as in the Greek church. Its text having become corrupted by frequent transcription, Origen undertook to revise it, and produced his celebrated 'Hexapla.' [Origenes, in Biog. Div.]

At the end of the 3rd and the beginning of the 4th centuries, three recensions of the text of the Septuagint were produced. The first was undertaken by Lucian, a presbyter of Antioch, who suffered martyrdom A.D. 311. This edition was conformed to the Hebrew text, and was received in the churches from Antioch to Constantinople. The second was edited at the same time by Hesychius, an Egyptian bishop. It is not known whether he followed the Hebrew text or ancient manuscripts of the Septuagint; but his alterations appear to have been fewer than those of Lucian. His edition was received by the churches of Egypt, and is cited by Jerome as the 'Exemplar Alexandrinum.' The third was transcribed by Eusebius and Pamphilus from the text in the Hexapla, with the whole of Origen's critical marks. In process of time these marks became so altered by frequent transcription, that they were at length altogether omitted, so that it is now impossible to distinguish Origen's emendations from the original text. This edition was received by the churches of Palestine, and had a place in all libraries. All the subsequent editions of the Septuagint are founded upon these three recensions.

There have been many modern editions of the Septuagint; the earliest is the Complutensian in 1514–1517.

For an account of the other Greek versions of the Old Testament, see Aquila; Symmachus; Theodotion, in Biog. Div. (The 'Introductions' of Horne and Jahn, and the authorities quoted by them.)

SEQUESTRATION. [Benefice.]

SEQUESTRATION is a process by which the revenues of an ecclesiastical benefice are received and applied by persons other than the incumbent of it. It issues immediately from the bishop in all cases, but it may be founded upon proceedings commenced either in his own court or in the temporal courts. It is a mandate, in the nature of a warrant, addressed by the bishop to the parties who are to execute it. These are called sequestrators, and in general are the churchwardens of the parish. So far as regards their duties under the sequestration, they are a kind of bailiffs. They collect the fruits of the benefice, and apply them according to the directions they receive in each case.

The occasions on which a sequestration is founded on proceedings in the court of the bishop are various. There may be a sequestration where a living is vacant by death; in order to provide for the expenses of supplying the cure, and to preserve the surplus for the successor. Where the title to a living is in dispute, a sequestration may issue under which some third party collects the fruits, and, after defraying the salary of the curate and other necessary expenses of the benefice, retains the surplus for the party who may appear to be lawfully entitled. There are many occasions also where the bishop acting judicially may sequester a living, as where the parsonage-house is in decay, and the incumbent, after due admonition, which may be made by the archdeacon, fails for a period of two months to repair it. The payment of a curate's salary may also be enforced by sequestration.

Sequestrations founded on proceedings in the temporal courts occur under the following circumstances:—The sheriff, the ordinary ministerial officer of those courts, has no power to interfere with ecclesiastical revenues. When a judgment therefore has been obtained against a beneficed clergyman, and execution has issued upon it, and the clergyman has no lay property upon which the sheriff can levy, he makes a return that the defendant is a beneficed clerk having no lay fee within his bailiwick. The plaintiff may then sue out a writ addressed to the bishop, directing him to levy the amount upon the clergyman's ecclesiastical goods. The bishop upon this issues a sequestration, directing the sequestrators to levy the debt upon the profits of the benefice; or the plaintiff may sue out a sequestrari facias, addressed to the bishop. The bishop, under these circumstances, is said to be a kind of ecclesiastical sheriff; and the temporal courts, in so far as relates to his duties as such ministerial officer, have the same power over him as they have over the sheriff, and his duties are analogous. [Sheriff.] The sequestration ought to be forthwith published by reading it in church during divine service, and afterwards at the church-door. The party obtaining it may, on giving proper security, name his own sequestrators. Under either of those writs the plaintiff is entitled to the growing profits, until the whole sum endorsed upon it is satisfied, even although this should not occur till after the time at which the writ is returnable. The necessary expenses of the sequestration, &c., are also leviable under the writ. The lands are bound from the time of the delivery of it to the bishop.

Sequestration in chancery is a "writ issuing out of the court, directed to four or more commissioners, empowering them to enter into a defendant's real estates, and to sequester into their own hands not only the rents thereof, but also all his goods, chattels, and personal estate whatsoever, to keep the same until the defendant has fully answered his contempt." It issues upon the occasion of their committing a contempt against the court, by keeping out of the way of the serjeant-at-arms, or escaping from custody, or disobeying an order of the court to pay money.

Sequestration also may be issued from the Courts of Common Law against a corporation, to compel obedience to a mandamus or injunction.

SEQUESTRATION (Scotland). [BANKRUPT LAWS OF SCOTLAND.]

SEQUIN. [MONEY.]

SERA'GLIO, properly *serai*, the palace of the Sultan of Turkey; in this sense the word is also applied to the houses of foreign ambassadors resident at his court. The seraï of Constantinople stands in a beautiful situation, on a head of land projecting into the sea, formerly called Chrysoceras, or the Horn of Gold, now Seraglio Point. The walls embrace a circuit of about three miles. Its outward appearance is not imposing, though its extent is large. The principal entrance, a large pavilion, which looks more like a guard-house than the entrance to a palace, is always guarded by *capidjis*, officers of the seraglio; but this is the Porte, from which the title of the Sublime Porte has arisen. That part of the building which is occupied by the women of the sultan has been improperly called *seraglio*, and hence the word has become synonymous with *harem*, an Arabic word, meaning "sacred spot," or that part of the house where the women and daughters of the Mohammedans reside.

SERAI, a large building for the accommodation of travellers, common in Eastern countries. The word is Persian, and means in that language, "a palace, the king's court, a large edifice;" hence *karávánserai*, by corruption *caravansarie*, that is, place of rest for caravans. In Turkey these buildings are generally called *khans*, from *khán*, another Persian word, which has a similar meaning. In Tartary and India they are simply called *serais*. The erection of these buildings is considered highly meritorious by Hindus as well as Mohammedans, who frequently endow them with rents for their support. [SERAGLIO.]

SERALBUMEN. [OVALBUMEN.]

SERAPEUM, the name given to two celebrated Egyptian temples, one at Alexandria, the other at Memphis, dedicated to the god Serapis. There was also a temple of the same name at Babylon, where the friends of Alexander the Great wished to transport him during his last illness (Arrian, 'Anab.,' vii. 56.) The temple of Serapis at Alexandria was preceded by an older one dedicated at Rhacotis. (Jul. Valer., 'Alex. Ort.,' I. xxxi.) All these temples derived their name from the god Serapis, who was affirmed by Manetho to be Pluto, or the Jupiter of Sinope. (Plutarch, 'Isid and Osirid,' xxxvii.) Of the many etymologies proposed for the name of the god, that of St. Clement of Alexandria is now recognised to be the correct one, Serapis being composed of two words signifying the Osiris, or deceased Apis, from the name of Osiris having been applied to all mortals after death, and to the bull considered as a demigod. Recent discoveries at Memphis have shown that the Serapeum was the cemetery of the Apis, and close to the Apeum where the bull dwelt during his life. The Apeum was established here after the time of the Psammetichi, where it still existed in the days of Herodotus (ii. 21). But the Serapeum or mortuary temple of the Apis was founded by Shaemgam, the son of Rameses II., who removed thither the tomb of the sacred bull. This temple was discovered by M. Mariette, at the west end of a dromos of sphinxes lying to the north of the Pyramids of Sakkara. It seems to have been enlarged and repaired till the days of Neththerhebi or Nectanebes I., of the 30th dynasty. Another temple, lying on the east end of the same dromos, seems to have been that erected in Ptolemaic times, and continued to be used for the Apis and the worship of Serapis till the days of the Emperor Julian, and even later. This Serapeum at Memphis was called the Great, to distinguish it from that of Alexandria, which was surnamed "the most illustrious." It comprised, or was a portion of, a group of buildings, consisting of the Astarteum, dedicated to Astarte; the Anubeum, to Anubis; the Asclepeum, or Temple of Æsculapius, in which libations were daily offered; the dwellings of the hierarchy; and the apartments or hospital of the sick who flocked to the temple for the sake of the cure of their maladies, which was supposed to be effected through the dreams accorded by the god during their sleep in the sacred edifice. One hundred and forty-six papyri discovered in the adjacent ruins, and now dispersed through the museums of Europe, relating to the quarrels and litigations of the functionaries of the temple, have thrown great light on its administration. They all date from the 18th to the 24th year of Ptolemy Philometor, and describe the temple as connected by a dromos of sphinxes with the city of Memphis, and which had not then, as in the days of Strabo, been buried in the sand. (Strabo, xvii. 807, c.) The temple was under the direction of prefects, delegates, vicars, subadministrators, and storekeepers, and two female priestesses called Didymi, or "twins," whose office was to serve Æsculapius and Serapis, and a peculiar class of hierodules, who voluntarily dedicated themselves to the service of the gods, and lived in celibacy and seclusion within the precincts. These persons derived no support from the revenues of the temple, and were either maintained by their families or the alms of visitors to the sacred edifice. They had in their hands the charge of affairs, but could not go beyond the precincts, and lived to all intents a cloistered or monastic life. This institution is mentioned as late as Antoninus Pius, and is evidently that from which monachism has been borrowed. (Peyron, B., 'Papiri Greci,' p. 14.) There were also many officers attached to the worship of the Apis, who had two shrines, into which he entered at pleasure, and from which passage augury was taken by the priests. The sacred bull was attended by a herdsman while living, and an entaphiastes or embalmer when dead. (Peyron, B., 'Papiri Greci,' p. 8.) His mother also participated in his honours, and had a shrine assigned her in the Apeum. Extraordinary care and vast sums were expended both by native and Greek monarchs in embellishing these shrines; and if the old capital of Memphis was comparatively neglected during the sway of the great Theban dynasties, this was amply compensated by the magnificent donations of the later Saitic dynasty and the Ptolemies. Apis is mentioned on monuments of the 4th dynasty, and his shrine must have been established as early as the building of the oldest Pyramids.

The remains of this edifice were discovered in the plains of Sakkara, in 1850 by M. Mariette, then an employé of the Louvre, who had been sent to Egypt to collect Coptic manuscripts for the French government, where he first found the dromos of sphinxes connecting the temples. This excavation was a work of great labour, the dromos having been made through the ancient cemetery of Sakkara, and curved to avoid injuring the tombs, and partly buried under a great depth of sand; after excavating a length of 7000 feet and uncovering 141 sphinxes, he discovered at the end of the avenue a semicircle ornamented with statues of the sages, poets, and philosophers of ancient Greece, supposed to have formed part of the library of the Serapeum. Between this semicircle and the two last sphinxes he found a transverse avenue, the right branch of which led to a temple erected to Apis by the monarch Nectanebes, or Neththerhebi; the left branch, paved with large stones, led to the Serapeum itself. The dromos was about 860 feet in length, flanked on each side by a low wall, divided on the left side about the middle by a small Greek building having before it a nos in which was a statue of Apis, probably that described by Strabo. On each side of the temple and on the wall, were allegorical figures of boys riding on chimeras and animals, and at the end of the dromos were the pylons or gateways of the Serapeum.

The wall, built in the reign of Neththerhebi, was covered with sepulchral altars, and 428 small bronze votive figures of deities were discovered in a niche. At this stage, owing to difficulties with the Egyptian government, the excavations were stopped in 1851, and not resumed till the spring of 1852. In November of 1851, the first tombs of the Apis were discovered, 640 sepulchral tablets, five entrances, and various small objects. This great subterraneous cemetery divided itself into two parts, the first of which had its entrance at the south end, and went in a northern direction forming a vaulted gallery like a tunnel, having at its side about 20 chambers, the oldest of the age of Rameses II., and the most recent of that of Psammetichus I. During this period the remains of 24 Apis mummies showed that this number of generations of cattle had lived and died during that chronological period. The other part of the cemetery was a souterrain divided into a considerable number of galleries, commenced in the 52nd year of Psammetichus I., and continued till the commencement of the Roman Empire. The bull mummies of this division were deposited in gigantic monolith sarcophagi of Syenitic granite, transported from the quarries above the first cataract. These sarcophagi ranged from 11 to 12 feet high, 14 to 15 feet long, and weighed 6500 kilogrammes; or above 64 tons, 24 of them were found in the 40 chambers of this tunnel. The tablets were not fixed to the inner walls but to the lintels of the doors, and were chiefly inscribed in demotic characters, and the most important one was placed in the midst of the wall which closed the door of the chamber, containing the dates of the birth, enthronement, death, and burial of the Apis. Only four of these sarcophagi had inscriptions, one bore the date of the 2nd year of Khabash, a Persian king, supposed to be later than Darius; another that of the reign of Cambyses; a third in that of Amasis II.; and the last that of Ptolemy. The result of these researches showed that the bull, said to have been stabbed by Cambyses, survived till the reign of Darius. Among the mummies of the Apis were found two others of men, evidently of the highest rank, who had been buried with the sacred bulls. The bulls which died from the commencement of the reign of Amenophis III. to the middle of that of Rameses II., had a mortuary chapel with four columns erected above the tomb, which was a chamber with a flat roof hollowed in the solid rock below, and the votive tablets of the adorers of the deceased bull were built into the stylobate of the mortuary chapel. The bull was treated as a deceased human being, and the sarcophagi were accompanied by sepulchral vases, and the visitors to the tomb deposited the usual sepulchral figures offered to the dead; but at the later period of the age of Rameses the tombs consisted of chambers on each side of the gallery, with the votive tablets placed in the gallery; and the sepulchral figures, deposited in the cases, were strewn along the floor, or inserted into niches in the wall. After the 53rd year of Psammetichus II., the chambers became more magnificent, being above 30 feet high, with vaulted roofs of white limestone, and the walls faced with stone from the Tourah quarries; the sarcophagi were of the finest red Syenite. At the period of the 30th dynasty the tablets were not allowed to be placed inside the tomb, but were restricted to the entrance, and the walls of the roads conducting to the tomb. After the epoch of Darius, the tombs are far less magnificent. The Apis of Cambyses is deposited in the vestibule of that which died in the 4th year of Darius. All the sacred bulls were not buried with the same honours, those most carefully embalmed having their principal bones placed in a wooden coffin inside the granite sarcophagus; others were cast into a hollowed place in the rocky pavement, and covered with a mere flagstone. The tablets found consisted chiefly of hieroglyphical inscriptions intermixed with demotic, commencing with the 15th year of Darius, and consisted of two classes: the sepulchral, or tombstones of the bull, on which was inscribed the date of the death of the sacred bull, that of his birth, and of his installation at Memphis, and the age which he had reached; and votive tablets dedicated by individuals to the departed Apis for the usual benefits supposed to be accorded by the gods. About 1200 of these tablets were found, and they have thrown great light upon the chronological period and succession of the monarchs of the 21st and 22nd dynasty. Altogether, 7000 objects were found, 3000 of which referred to the worship of Apis, a number by no means remarkable when it is considered that Ptolemy I. spent about 10,000*l.* on the funeral of an Apis. The sepulchres were of bulls which died in the following reigns—Amenophis III., Amenankhut, Horus, and Khuenaten, of the 18th dynasty; of Sethos I. and Rameses II., three of which happened in the 16th, 26th, and 30th years of the last-named monarch, of the 19th dynasty; of Rameses III., V., VIII., XIV., of the 20th dynasty; of Osorchon II., Takelothis I., Sheshonk III., IV., of the 22nd dynasty; of Boochoris, of the 24th dynasty; of Sabaco and Tirhaka, of the 25th dynasty; of Psammetichus I., II., and Aahmes, of the 26th dynasty; of Cambyses, Darius, and Khabash or Smerdis, of the 27th dynasty; of Neththerhebi, of the 30th dynasty. The tablets subsequent to this reign, chiefly demotic, consist of votive inscriptions in honour of Apis, and they gave the following dates for the appearance of the Apis: B.C. 258, in the 32nd year of Ptolemy Philadelphus; B.C. 231, the 20th year of Euergetes; B.C. 210, the 14th year of Ptolemy Philopator; B.C. 185 and 165, in the reign of Ptolemy Philometor; B.C. 142, the 13th year of Ptolemy Euergetes II.; and B.C. 117, in the reign of Ptolemy Euergetes II. The temple of Æsculapius was also partially uncovered by M. Mariette, but tradition had assigned the spot to be the prison of Joseph, and the work could not be carried on.

(Mariette, Aug. *Choix de Monuments decouverts pendant le déplacement du Serapeum de Memphis*, 4to, Paris, 1856; *Memoire sur la mère d'Apis*, 4to, Paris, 1856; *L'Athenæum Français*, 1855, 1856.)

SERAPHINE, a musical instrument of the keyed kind. It may be described as a small organ, in which short, thin, and narrow steel bars, or springs, put into vibratory motion by means of a bellows acted on by the foot, are used instead of pipes. It was one of the predecessors of the HARMONIUM, which now takes the place of such instruments as are not portable. The portable forms are represented by the CONCERTINA. See also ACCORDION.

SERAPIS. [SERAPEUM.]

SERENADE, a word adopted from the French *sérénade*, which is derived from the Italian and Spanish *serenata*, a term formed from the Latin *serenus*, clear, serene. A serenade is properly music performed in the open air on a serene night, but is generally restricted to a musical performance given at night by a lover to his mistress under her window. The giving of serenades is little practised except by the Spanish and Italians, who generally on these occasions use the guitar as an accompaniment to their songs.

SERIES. The mathematical meaning of the word series is, a set of terms, finite or infinite in number, connected together by addition or subtraction, and formed upon some distinct law. If it had been the plan of this work to write treatises on the various branches of pure mathematics, the present article would have been brief, and abounding in references to the articles on algebra and the differential calculus, the most important results of which are expressed in series; but in a work which, without entering into such full details, professes to furnish references to the most important detached doctrines of the exact sciences, the present article must extend to some length.

Series may be either finite or infinite in the number of their terms. As to finite series, such for instance as 'x terms of $1+2+3+\ldots.$,' the only question of importance which generally arises with respect to them is, how to express the sum as a function of the indefinite number of terms, x. On this point we refer to the articles INTEGRATION, FINITE, and SUMMATION: it is with the doctrine of infinite series that the mathematician is more particularly concerned in the present article. Again, as to the manner in which the differential calculus is applied to the development of functions in series, we refer to TAYLOR'S THEOREM.

A series of an infinite number of terms may be either purely numerical, as $1+2+3+4+\ldots\ldots$, in which the symbol $+\ldots$, or $+$, &c., means that the series is to be carried on for ever, the law of formation of the written terms being continued through all the unwritten ones; or it may contain literal expressions with an obvious law of formation, as in $1+2x+3x^2+\ldots.$ A series of the latter class is reduced to one of the former so soon as any definite value is given to the letters it contains.

An infinite series may be either convergent or divergent, as explained in the article CONVERGENT. The various tests there explained will perhaps serve to settle this point as to the greater number of series actually employed; but the following ('Diff. Calc.,' 'Lib. of Useful Knowl.,' pp. 236, 326; we shall refer to this work in the sequel under the letters D. C.) will leave no doubtful case, though its application may sometimes be troublesome.

Let ψx be the xth term of a series $\psi 1+\psi 2+\psi 3+\ldots.$ (thus a^{x-1} is the xth term of $1+a+a^2+\ldots.$; $x a^{x-1}$ of $1+2a+3a^2+\ldots.$), and let $\mathrm{P}_0=-x\psi' x:\psi x$, $\psi' x$ being the differential coefficient of ψx. Let a_0 be the limit of P_0 when x increases without limit; then if a_0 be greater than 1, the series is convergent; if a_0 be less than 1 (negative quantity included), divergent; if $=1$, doubtful.

In the doubtful case of the preceding, let $\mathrm{P}_1=\log x\,(\mathrm{P}_0-1)$, and let a_1 be its limit when x increases without limit. Then if a_1 be >1, the series is convergent; if <1, divergent; if $=1$, doubtful. In this doubtful case examine $\mathrm{P}_2=\log\log x\,(\mathrm{P}_1-1)$, of which let the limit be a_2. Then if $a_2>1$, the series is convergent; if <1, divergent; if $=1$, doubtful; and so on. In brief, take the set of quantities

$$\mathrm{P}_0=-x\,\frac{\psi' x}{\psi x},\ \ \mathrm{P}_1=\log x\,(\mathrm{P}_0-1),\ \ \mathrm{P}_2=\log\log x\,(\mathrm{P}_1-1),$$
$$\mathrm{P}_3=\log\log\log x\,(\mathrm{P}_2-1),\ \text{\&c. \&c.};$$

make x infinite; then, according as the first of these which differs from unity is greater than or less than unity, the series is convergent or divergent. If it be more convenient to write $1:\phi x$, instead of ψx for the xth term of the series, then P_0 must be $x\phi' x:\phi x$, instead of $-x\psi' x:\psi x$. Nor need ψx be the xth term; it may stand for the $(x+n)$th term, n being constant.

By the symbol $\mathrm{s}\phi x$ is here meant the series $\phi x+\phi(x+1)+\phi(x+2)+\ldots.$; but when a number is written beneath s, as in s_2, it indicates the value of x in the first term of the series. Thus $\mathrm{s}_4 x$ stands for $4+5+6+\ldots.$, $\mathrm{s}_a\log x$ stands for $\log a+\log(a+1)+\ldots.$ Some such abbreviation is most wanted in an article of reference, in which compression is desirable; but the student should write his series at more length until he is well accustomed to them.

A divergent series is, arithmetically speaking, infinite; that is, the quantity acquired by summing its terms may be made greater than any quantity agreed on at the beginning of the process. Such is evidently the case with $1+2+4+\ldots.$, or $\mathrm{s}_0 2^x$. Nevertheless, as every algebraist knows, such series have been frequently used as the *representatives of finite quantities*. It was usual to admit such series without hesitation; but of late years many of the continental mathematicians have declared against divergent series altogether, and have asserted instances in which the use of them leads to false results. Those of a contrary opinion have replied to the instances, and have argued from general principles in favour of retaining divergent series. Our own opinion is, that the instances have arisen from a misunderstanding or misuse of the series employed, though sufficient to show that divergent series should be very carefully handled; but that, on the other hand, no perfectly general and indisputable right to the use of these series has been established *à priori*. They appear always to lead to true results when properly used, but no demonstration has been given that they must always do so.

Before, however, we proceed to reason upon them, we must distinctly understand what we mean by an *infinite* series. Some persons cannot imagine an infinite series, except by means of successions of finite terms: thus they have no other idea of $1+2+4+8+\ldots$, except as something of which the conception is a pure result of the successive consideration of 1, $1+2$, $1+2+4$, $1+2+4+8$, &c. If they can get no further than this, that is, if at no stage of their contemplation can they treat $1+2+4+\ldots$ as anything more than carried to some enormous number of terms, with a right to carry it further; we can then concede to them the right to object, in the manner described, to the use of a divergent series, though we think it possible that even in this case an answer might be given to the objection. But if there be any who can with us carry their notions further, and treat the series as *absolutely endless*, in the same manner as we are obliged to conceive time and space to be absolutely endless, looking upon the result not as to its arithmetical value, but as to its algebraical form and capability of being the object of algebraical operations—we then think that we have those with whom the question of divergent series can be argued on something more like a basis of demonstration. They may arrive at the final idea by means of the successions which the first class of thinkers say *must end somewhere*; but they answer, that this is no more true than that space must end somewhere: if it be granted that we are capable of conceiving a straight line extended without limit, with equal parts set off throughout its total infinite length, it must equally be granted that we might suppose one term of a series written at each and every point of subdivision. To this issue the question might be brought, namely, the alternative of allowing the conception of the infinite series, or of denying that of the infinite straight line. And it must be remarked that the considerations by which we limited the use of the word INFINITE in that article do not apply here, for we are not reasoning upon any supposed * attainment of the other end of the straight line, but upon ideas derived from a process of successions carried on during such attempt as we can make in our thoughts towards that attainment.

This being premised, let us now consider the series $1+a+a^2+a^3+\ldots$

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* Indeed it is only a phraseological attainment of infinite magnitude which is used in the article cited: when we *say* that $a=b$ if x be infinite, we mean that a and b never cease to approach each other so long as the value of x increases.

ad infinitum, the last words being used strictly in the above sense, without reference to any particular value of a, and only as an object of algebraical operation. To what finite function of a is this an algebraical equivalent in all matters of operation? Let us consider first merely results of operation, without any question as to whether the series operated on have values or not, or whether expressions which appear to be the same so far as operations are concerned, are to be the same in value or not, when any difficulty arises as to the value of either. We assume those five rules of operation and their consequences, on which [OPERATION] the technical part of algebra is founded. If we then call the preceding series P, we find that P and $1+a\,\mathrm{P}$ are the same series. If then $\mathrm{P}=1+a\,\mathrm{P}$, we find $\mathrm{P}=1:(1-a)$, a result which is certainly not true in any arithmetical point of view, when $a>1$; for in such a case the series is infinite, and the finite expression negative. Leaving this, let us assume, for trial if the reader pleases, the equation $1:(1-a)=\mathrm{s}_0 a^x$; in this change a into $1:a$, and add, which gives

$$\frac{1}{1-a}+\frac{a}{a-1}=2+\mathrm{s}_1 a^x+1+\mathrm{s}_1 a^{-x}$$

or $1+\mathrm{s}_1(a^x+a^{-x})=0$, a result which is again perfectly incongruous in an arithmetical point of view. At full length it is

$$1+a+\frac{1}{a}+a^2+\frac{1}{a^2}+\ldots\ldots=0.$$

To test this curious result, by operations merely, call it ϕa, and multiply $\mathrm{A}+\mathrm{B}a+\mathrm{C}a^2+\ldots\ldots$ by it: the result, by common rules, will be found to be

$$(\mathrm{A}+\mathrm{B}+\mathrm{C}+\ldots\ldots)\,\phi a=(\mathrm{A}+\mathrm{B}a+\ldots\ldots)\,\phi a;$$

a result which agrees perfectly with $\phi a=0$, and with no other supposition whatsoever.

A great many other instances might be given, in which the use of $\phi a=0$ makes sense, so to speak, of results in the formation of which ϕa has been used. And it is generally admitted that divergent series are found to make sense, in the same manner, of almost every result in the formation of which they are used; and also that when such results happen themselves to be free of divergency, there is very rarely any distinction, as to either truth or clearness, between them and the results of ordinary algebra; insomuch that the objection of those who would avoid them altogether, as usually stated, amounts, so far as operations are concerned, to the assertion that they *sometimes* give false results.

If we then compare the position in which we stand with respect to divergent series, with that in which we stood a few years ago with respect to impossible quantities, we shall find a perfect similarity. The divergent series, that is, the equality between it and a finite expression, is perfectly incomprehensible in an arithmetical point of view; and so was the impossible quantity. The use of divergent series has been admitted, by one on one explanation, and by another on another, almost ever since the commencement of modern algebra; and so it was with the impossible quantity. It became notorious that such use generally led to true results, with now and then an apparent exception, which most frequently ceased to be such on further consideration; this is well known to have happened with impossible quantities. In both cases these apparent exceptions led some to deny the validity of the method which gave rise to them, while all were obliged to place them both among those parts of mathematics (once more extensive than now) in which the power of producing results had outrun that of interpreting them. But at last came the complete explanation of the impossible quantity [ALGEBRA], showing that all the difficulty had arisen from too great limitation of definitions; and almost about the same time arose that disposition among the continental writers, of which we have spoken above, namely, to wait no longer for the explanation of the true meaning of a divergent series, but to abandon it altogether. But why should the divergent series, of all the results of algebra which demand interpretation, be the only one to be thrown away without further inquiry, when in every other case patience and research have brought light out of darkness.

So far as the matter has yet gone, very little has been done towards the interpretation of a divergent series independently of its involopment, or function from which it is developed. When this involopment is known, and the series deduced from it, there are means of stopping the divergency, by arresting the development at any given point, and turning the remainder, not into a further development, but into a finite form. Thus if ϕx, a given function of x, should give a divergent series $\mathrm{A}_0+\mathrm{A}_1x+\ldots\ldots$, all that part of the development which follows $\mathrm{A}_n x^n$ may be included in

$$\int_0^x \phi^{(n+1)}(x-v)\,v^n dv\ :\ 1.2.3\ldots\ldots n.$$

This will be proved in TAYLOR'S THEOREM, and it is a result of great importance, because it gives the means of removing all the doubtful points of divergent series from the ordinary branches of mathematics.

Next to the question of convergency or divergency, comes that of continuity or discontinuity. We are not here speaking of continuity of value, but of form. A series is continuous when for all values of x it represents the same function of x. Thus $\mathrm{s}_0 x^n$ or $x^0+x^1+x^2+\ldots$, is in all cases the development of $(1-x)^{-1}$, whether it be convergent or divergent. Even those who reject divergent series altogether, though they would call this series, when $x>1$, a false or inadmissible development of $(1-x)^{-1}$, would not, though they reject it, look upon it as possible to arise from any other function. But the series

$$\mathrm{s}_1(-1)^{n+1}\frac{\sin n\theta}{n}\ \text{or}\ \sin\theta-\frac{\sin 2\theta}{2}+\frac{\sin 3\theta}{3}-\ldots$$

is discontinuous; for certain values of θ it represents one function, and for other values another. When θ is any multiple of π [ANGLE] it is $=0$; when θ falls between $-\pi$ and $+\pi$, it is $\frac{1}{2}\theta$; when θ falls between π and 3π, it is $\frac{1}{2}\theta-\pi$, &c.; in fact, it stands for $\frac{1}{2}\theta-m\pi$, where m is to be so taken that $\frac{1}{2}\theta-m\pi$ shall fall between $-\frac{1}{2}\pi$ and $+\frac{1}{2}\pi$. Again, the series

$$\mathrm{s}_0\frac{a^n x}{(1+a^n x)(1+a^{n+1}x)}=\frac{1}{(a-1)(x+1)}\ \text{or}\ \frac{x}{(1-a)(x+1)}$$

according as $a>1$ or <1: and when $a=1$, it is infinite. Remember that by calling a series infinite we do not merely mean that it is divergent, for a divergent series may be the development of a finite quantity; thus $1+2+4+\ldots\ldots$ is a development of -1 from the form $(1-2)^{-1}$. But we mean that the *arithmetical value* of the function developed is infinite when we say that the series is infinite.

Discontinuity of form may be in many cases avoided by an extension of the modes of algebraical expression. Thus if we write down the expression

$$\frac{1}{a-1}\left\{\frac{1}{x+1}-\frac{1}{a^k x+1}\right\}$$

and consider k as having a very great value, the second term will be very small or very near to unity, according as a is >1 or <1. If we introduce the symbol a^∞ as representing ∞ when $a>1$, and 0 when $a<1$, we have, on putting ∞ for k, the representation of both forms of the preceding series in one. We shall now proceed to point out some of the principal modes of transforming series into others, or deducing others from them, so far as this is done without interfering with the developments in TAYLOR'S THEOREM.

1. If ϕx can be developed into $a+a_1x+a_2x^2+\ldots$, then $ab+a_1b_1x+a_2b_2x^2+\ldots$ can be developed as follows (D. C., p. 239). Let the last be ψx, and from b, b_1, b_2, &c. [DIFFERENCE] form Δb, $\Delta^2 b$, &c.: then

$$\psi x=b\phi x+\Delta b\,.\,x\phi' x+\frac{\Delta^2 b}{2}x^2\phi'' x+\frac{\Delta^3 b}{2\,.\,3}x^3\phi''' x+\ldots$$

where $\phi' x$, $\phi'' x$, &c., are the successive differential coefficients of ϕx. If b, b_1, &c. be values of a rational and integral function of n, denoted by b_n, the preceding is not an infinite series, but a finite expression. We have not room for examples, and it is to be remembered that this is an article of reference. Particular classes of instances are

$$b+b_1x+\ldots=\frac{b}{(1-x)}+\frac{\Delta b\,.\,x}{(1-x)^2}+\frac{\Delta^2 b\,.\,x^2}{(1-x)^3}+\ldots$$

$$b+nb_1x+n\frac{n-1}{2}b_2x^2+n\frac{n-1}{2}\frac{n-2}{3}b_3x^3+\ldots=$$

$$(1+x)^n\left\{b+n\Delta b\frac{x}{1+x}+n\frac{n-1}{2}\Delta^2 b\left(\frac{x}{1+x}\right)^2+\ldots\right\}$$

$$b+b_1x+b_2\frac{x^2}{2}+b_3\frac{x^3}{2\,.\,3}+\ldots=\varepsilon^x\left(b+\Delta bx+\Delta^2 b\frac{x^2}{2}+\ldots\right)$$

the preceding is a case of more general theorem (D. C., p. 565) from which the following may also be deduced:—

$$b+b_1x+\ldots=\frac{b}{1+mx}+\frac{\nabla b\,.\,x}{(1+mx)^2}+\frac{\nabla^2 b\,.\,x^2}{(1+mx)^3}+\ldots$$

$\nabla b=b_1+mb$, $\nabla^2 b=b_2+2mb_1+m^2b$, &c. By this theorem many divergent series may be converted into convergent ones, or the convergency of convergent series may be increased.

2. Let $r=\sqrt{(1-2\cos\theta\,.\,x+x^2)}$, $\tan\phi=\dfrac{x\sin\theta}{1-x\cos\theta}$.

Then $b+b_1\cos\theta\,.\,x+b_2\cos 2\theta\,.\,x^2+b_3\cos 3\theta\,.\,x^3+\ldots=$

$$\cos\phi\frac{b}{r}+\cos(\theta+2\phi)\frac{\Delta bx}{r^2}+\cos(2\theta+3\phi)\frac{\Delta^2 b\,.\,x^2}{r^3}+\ldots$$

and $b_1\sin\theta\ x+b_2\sin 2\theta\,.\,x^2+b_3\sin 3\theta\,.\,x^3+\ldots=$

$$\sin\phi\frac{b}{r}+\sin(\theta+2\phi)\frac{\Delta b\,.\,x}{r^2}+\sin(2\theta+3\phi)\frac{\Delta^2 b\,.\,x^2}{r^3}+\ldots$$

3. Let ϕx be a rational and integral function of x; then

$$\phi x+\phi(x+1)\,.\,a+\phi(x+2)\,.\,a^2+\ldots=\frac{1}{1-a}\phi x+$$

$$\frac{a}{(1-a)^2}\phi' x+\frac{a+a^2}{(1-a)^3}\frac{\phi'' x}{2}+\frac{\mathrm{A}_3}{(1-a)^4}\frac{\phi''' x}{2\,.\,3}+\ldots.$$

$$\mathrm{A}_3=a+4a^2+a^3,\ \mathrm{A}_4=a+11a^2+11a^3+a^4$$

$$\mathrm{A}_5=a+26a^2+66a^3+26a^4+a^5,\ \text{\&c.}$$

$$\mathrm{A}_6=a+57a^2+302(a^3+a^4)+57a^5+a^6.$$

This must lead to a finite expression for the series, and is frequently the shortest way of obtaining it.

4. Let $z = \epsilon^{\theta\sqrt{-1}} = \cos\theta + \sqrt{-1}\,.\,\sin\theta$ and $\phi x = a + a_1 x + a_2 x^2 + \dots.$

$$\frac{1}{2}\left\{\phi(zx) + \phi\left(\frac{x}{z}\right)\right\} = a_0 + a_1 \cos\theta\,.\,x + \dots.$$

$$\frac{1}{2\sqrt{-1}}\left\{\phi(zx) - \phi\left(\frac{x}{z}\right)\right\} = a_1 \sin\theta\,.\,x + \dots.$$

the series resembling those in (2). Further varieties will appear in TAYLOR'S THEOREM.

5. If $\phi(0) + \phi(1)\,.\,x + \phi(2)\,.\,x^2 + \dots.$ be the development of a perfectly continuous function of x, and if ϕn be a function which never becomes infinite for any real value of n, positive or negative; then the same function may be also developed into $-\phi(-1)\,.\,x^{-1} - \phi(-2)\,.\,x^{-2} - \phi(-3)\,.\,x^{-3} - \dots.$ (D. C., p. 560).

6. If $\phi x = a_0 + a_1 x + a_2 x^2 + \dots.$ and if $\rho_1, \rho_2, \dots \rho_n$ be the n nth ROOTS of unity, then (D. C., p. 319)

$$a_0 + a_n x^n + a_{2n} x^{2n} + \dots = \frac{\phi(\rho_1 x) + \dots + \phi(\rho_n x)}{n}$$

$$a_1 x + a_{n+1} x^{n+1} + \dots = \frac{\rho_1^{\,n-1}\phi(\rho_1 x) + \dots + \rho_n^{\,n-1}\phi(\rho_n x)}{n}$$

$$a_2 x^2 + a_{n+2} x^{n+2} + \dots = \frac{\rho_1^{\,n-2}\phi(\rho_1 x) + \dots + \rho_n^{\,n-2}\phi(\rho_n x)}{n}$$

and so on. Also if we make ρ_1, ρ_2, &c., the nth roots of -1, and use the same results, only altering the multipliers into $\rho_1^{\,2n-1}$, &c., $\rho_1^{\,2n-2}$, &c., we have the sums of the same series with the terms alternately positive and negative.

7. One of the simplest modes of actually finding a finite expression for a series, finite or infinite, the coefficients of which are values of a rational and integral function, is the continual multiplication by $1-x$, which must at last produce a finite expression. It must be remembered that multiplication by $1-x$ may be performed by letting the first coefficient remain, and diminishing every other coefficient by its predecessor. Thus $a + bx + cx^2 + ex^3 + \dots.$ multiplied by $1-x$ gives $a + (b-a)x + (c-b)x^2 + (e-c)x^3 +$. And a finite series must be supposed to be continued *ad infinitum* with vanishing coefficients. For example, it is required to find a finite expression for $1^3 + 2^3x + 3^3x^2 + \dots$; write this as in the first line, and make successive multiplications by $1-x$, as in the following lines:—

$$\begin{array}{l} 1 + 8x + 27x^2 + 64x^3 + 126x^4 + \dots \\ 1 + 7x + 19x^2 + 37x^3 + \;\; 61x^4 + \dots \\ 1 + 6x + 12x^2 + 18x^3 + \;\; 24x^4 + \dots. \\ 1 + 5x + \;\; 6x^2 + \;\; 6x^3 + \;\;\; 6x^4 + \dots. \\ 1 + 4x + \;\;\; x^2 + \;\; 0x^3 + \;\;\; 0x^4 + \dots. \end{array}$$

After four multiplications, then, by $1-x$, the series becomes $1 + 4x + x^2$; whence its value is—

$$\frac{1 + 4x + x^2}{(1-x)^4}$$

Independently of the modes of deriving series obtained from Taylor's Theorem, and of which we are to speak elsewhere, there are two modes of forming them which deserve attention. The first depends upon the numbers called the differences of nothing [NOTHING, DIFFERENCES OF]; the second on those called NUMBERS OF BERNOULLI.

By the first of these any function of ϵ^x can be expanded in powers of x.

$$f\epsilon^x = f1 + f(1+\Delta)\,0\,.\,x + f(1+\Delta)\,0^2\,.\,\frac{x^2}{2} + \dots$$

Here $f(1+\Delta)\,0^n$ is a symbol of the calculus of operations [OPERATION], which expanded is—

$$f1\,.\,0^n + f'1\,.\,\Delta 0^n + \dots. + f^{(n)}1\,\frac{\Delta^n 0^n}{2\,.\,3\dots n}$$

it being unnecessary to go further, because $\Delta^m 0^n = 0$ whenever m is greater than n. (D. C., 307.)

The numbers of Bernoulli occur first in the development of $(\epsilon^x - 1)^{-1}$, a series the importance of which can only be estimated by its use in SUMMATION. Taking the numbers from the article cited above, or making

$$B_1 = \frac{1}{6}\;,\;\; B_3 = \frac{1}{30}\;,\;\; B_5 = \frac{1}{42}\;,\;\; B_7 = \frac{1}{30},\ \&c.$$

$$\frac{1}{\epsilon^x - 1} = \frac{1}{x} - \frac{1}{2} + \frac{B_1 x}{2} - \frac{B_3 x^3}{[4]} + \frac{B_5 x^5}{[6]} - \dots.$$

$$\frac{1}{\epsilon^x + 1} = \frac{1}{2} - \frac{3B_1 x}{2} + \frac{15B_3 x^3}{[4]} - \frac{63B_5 x^5}{[6]} + \dots.$$

where $[n]$ means $1\,.\,2\,.\,3\,\dots.\,n-1\,.\,n$.

We shall now give a number of series which are not of very frequent use, but which may sometimes be sought in a work of reference. Under the last predicament we can never suppose that any of the following developments would come: $(1+x)^n$, ϵ^x, a^x, $\log(1+x)$, $\log\frac{1+x}{1-x}$, $\sin x$, or $\cos x$. Some terms are given, and $\pm\dots.$ is omitted to save room.

$$\tan x = x + \frac{x^3}{3} + \frac{2x^5}{15} + \frac{17x^7}{315} + \frac{62x^9}{2835} + \frac{1382x^{11}}{155925}$$

$$\cot x = \frac{1}{x} - \frac{x}{3} - \frac{x^3}{45} - \frac{2x^5}{945} - \frac{x^7}{4725} - \frac{2x^9}{93555}$$

$$\sec x = 1 + \frac{x^2}{2} + \frac{5x^4}{24} + \frac{61x^6}{720} + \frac{277x^8}{8064}$$

$$\operatorname{cosec} x = \frac{1}{x} + \frac{x}{6} + \frac{7x^3}{360} + \frac{31x^5}{15120} + \frac{127x^7}{604800}$$

$$\sin^{-1} x^{*} = x + \frac{1}{2}\frac{x^3}{3} + \frac{1\,.\,3}{2\,.\,4}\frac{x^5}{5} + \frac{1\,.\,3\,.\,5}{2\,.\,4\,.\,6}\frac{x^7}{7}$$

$$\tan^{-1} x^{*} = x - \frac{x^3}{3} + \frac{x^5}{5} - \frac{x^7}{7}$$

$$\log\frac{x}{\sin x} = \frac{x^2}{6} + \frac{x^4}{180} + \frac{x^6}{2835} + \frac{x^8}{37800} + \frac{x^{10}}{467775}$$

$$\log\frac{1}{\cos x} = \frac{x^2}{2} + \frac{x^4}{12} + \frac{x^6}{45} + \frac{17x^8}{2520} + \frac{31x^{10}}{14175}$$

$$\log\frac{\tan x}{x} = \frac{x^2}{3} + \frac{7x^4}{90} + \frac{62x^6}{2835} + \frac{x^8}{2700} + \frac{32x^{10}}{467775}$$

These logarithms are the Naperian logarithms, as is always the case in analysis, unless the contrary be expressed (as it is usual to say, but it really never happens):

$$\frac{1}{\log(1+x)} = \frac{1}{x} + \frac{1}{2} - \frac{x}{12} + \frac{x^2}{24} - \frac{19x^3}{720} + \frac{3x^4}{160} - \frac{863x^5}{60480}.$$

We must again remind the reader that the symbol $+$, &c., or $-$, &c., is throughout omitted to save room.

There is one property of series which deserves particular notice (D. C., pp. 226 and 649) as creating a most remarkable distinction between those which have all their terms positive, and those which have them alternately positive and negative. The former, even if the terms diminish without limit, are not necessarily convergent; thus $1 + 2^{-1} + 3^{-1} + \dots.$ is divergent. But if the terms be alternately positive and negative, and diminishing without limit, the series is always convergent, and the error made by stopping at any term is less than the first of the terms thrown away. And the most remarkable part of the property is that this last is true, even if the series become divergent, by having its terms increasing without limit, instead of diminishing; so that if the terms diminish for a time, and then begin to increase, the portion of the series during which the diminution takes place may be made use of in approximating to its arithmetical value. That is, if A_1, A_2, be all positive quantities, and if the infinite series $A_1 - A_2 + A_3 - \dots.$ be carried as far as A_n, the error is less than A_{n+1}, whatever the law of the terms may be, or however rapidly they may afterwards increase. Let us take, for instance,—

$$1 - \frac{2}{x} + \frac{2\,.\,3}{x^2} - \frac{2\,.\,3\,.\,4}{x^3} + \frac{2\,.\,3\,.\,4\,.\,5}{x^4} - \dots.$$

Let x be ever so great, the rapid increase of the numerators must still make this series ultimately divergent. Nevertheless, if x be considerable, the first terms diminish so rapidly that, with the aid of the above theorem, a good approximation may be made to the arithmetical value of the function from which the series was derived. Let $x = 100$, whence the series becomes—

$$1 - \cdot02 + \cdot0006 - \cdot000024 + \cdot00000120 - \dots.$$

After the hundredth term the terms will begin to increase, and more and more rapidly; but the theorem enables us, when $x = 100$, to make the following assertions; first, 1 is too great, but not by so much as ·02; 1 − ·02, or ·98, is too small, but not by so much as ·0006; ·98 + ·0006, or ·9806, is too great, but not by so much as ·000024; ·9806 − ·000024, or ·980576, is too small, but not by so much as ·00000120; ·980576 + ·00000120, or ·9805772, is too great, but not by so much as the next term; and so on.

SERJEANT, or SERGEANT (*Serviens*). This term, in its original signification, has long become obsolete. It would however be difficult to trace the connection between the different officers to whom the term is now applied without going back to their common type.

The term serviens and servicium appear to have been applied at first to all servants of the public, or of the crown, as the head of the state, and to the service rendered by them as an acknowledgment or render for the lands held by such service. Rent paid by a tenant to his landlord is still distinguished by the name of rent-service [RENT] from other annual payments charged upon land, &c. The word "serjeant" comes to us from "sergent," into which the French had modified the Latin "serviens." The word serjeanty, in French "sergenterie," was

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[*] In these series the angle is less than a right angle, positive or negative.

formed from "sergent," but was always used with reference to a particular species of service.

The complete development of the feudal system which followed the Norman conquest, was greatly facilitated by those political struggles which terminated in placing large portions of the lands of the kingdom in succession at the disposition of the crown. The forfeited lands of the revolted English were granted by the Conqueror to his followers with few exceptions, subject to the performance of personal services regulated by the quantity of the land granted and the rank and qualification of the grantee. The services ordinarily reserved upon grants by the crown, and upon those made by inferior grantors to their military followers, were of a military character. Where the grant was to hold by the service of a knight's fee, or of two, or half a knight's fee, &c., without expressing the nature of the service to be performed, the party was said to hold by knight's service, *per servicium militare* [KNIGHT'S SERVICE]; but where some *particular* service was to be performed by the tenant, or by some duly qualified person provided by him,—as, to be an earl or baron of the realm, to lead the king's host, to assist in the defence of a certain castle, to wind a horn upon an invasion, &c.—the tenure was called tenure by serjeanty (*per serjeantiam*), and the grantee became a tenant by serjeanty, and would be a serjeant (*serviens*). Whilst the two tenures were always distinguished by the two appellations of "serjeantia" and "servicium militare," the term "serviens" or "serjeant" was applicable to a tenant belonging to either class who had not taken upon himself the order of knighthood.

As the tenant by serjeanty was commonly distinguished by some title derived from the nature of his service—as earl, baron, constable, marshal, treasurer, &c.—the name "serjeant" was usually applied, not to those who held in serjeanty, but to those who held *per servicium militare* generally, and had not been knighted. Thus in 1348 the four knights impanneled on a grand assize were told by the judge that they should elect no serjeants whilst they could find suitable knights (M. 22 Edw. III., fo. 18); and in 1352 the four knights, not being able to elect twelve other knights, were allowed, by the assent of parties, to elect of the most wealthy serjeants (H. 26 Edw. III., fo. 57, pl. 12). (These two cases have been strangely misunderstood by Dugdale and others, as if they related to an exemption of serjeants-at-law from the burthen of serving upon a grand assize.) So an ordinance was made in parliament in the reign of Edward III. (1362), by which the return of lawyers to parliament, as knights for counties, was prohibited, on the ground that they acted with a view rather to the benefit of their clients than to that of the public, and the elections were directed to be made of knights and of serjeants of the most value. The term serjeant is also applied to those inferior military tenants, in the grant of a subsidy in 1379, in which serjeants and franklins of the county are assessed at 6*s.* 8*d.*, or 3*s.* 4*d.*, according to their estate, whilst serjeants at law are assessed at a fixed sum of 40*s.*, being twice the amount of the assessment of barons of the realm. (3 'Rot. Parl.,' 58.)

The serjeant holding *per servicium militare*, if possessed of sufficient land, was however bound, when called upon, to take upon himself the obligations attendant upon the order of knighthood. The tenant, or expectant tenant of such an estate, who wished to qualify himself for the creditable discharge of knightly duties, usually entered upon a course of training in the capacity of esquire to some knight, into whose service he was induced to enter by considerations arising from family connection, tenure, or friendship, or from the opinion entertained of his military fame. Although from the time of the Conquest down to the latter end of the reign of Edward III. all military tenants who had not been knighted are designated "serjeants," we find that after the first years of the reign of Richard II. the term serjeant, as applied to the unknighted tenant by knight's service, disappears, and is succeeded by the "esquire," a term previously used not to designate a class of persons occupying a certain rank, but an office actually performed. ('Abb. Rot. Origin.,' 209, b.) The services of the serjeant of the 14th century, and those of his successor, the esquire of the 15th, were alike estimated as equal to one-half of the service of a knight-bachelor, or one-fourth of the service of a knight-banneret.

A special service of a military character, to be performed by the tenant or his sufficient deputy, was not less noble than the ordinary knight's service, and was sometimes called chivalerian serjeanty, but more commonly grand serjeanty. It is said, indeed, by Littleton (s. 153) to be a greater and more worthy service than the other. But any service, military or civil, which was to be performed by the tenant or his deputy to the king himself, was, on account of the dignity of the king's person, accounted a grand or chivalerian serjeanty. Thus, in the Germanic body, the offices of arch-chancellor, arch-treasurer, arch-butler, &c., of the empire, attached to particular electorates, were of equal dignity with that of arch-marshal of the empire held by another elector; and in England, the civil office of lord high treasurer, &c., the military office of lord high constable, &c., and the mixed office of lord high steward, &c., and that of earl or baron by tenure, are, or were, all equally held by grand serjeanty.

Lands held by serjeanty, on account of the entire nature of the service, could not lawfully be aliened or divided. This, however, was by a species of connivance frequently done in fact. The course was for the crown to issue a commission to fix a rent upon the alienated serjeanty, or the divided portions. By this process, tenancies in serjeanty gradually became nearly extinct before the abolition of military tenures. Sometimes, upon the escheat or forfeiture of a serjeanty, the lands were granted by the crown, to hold by knight's service, whereby the special service of the serjeanty was lost.

Where the services reserved upon the tenure bore some relation to war, but were required neither to be executed personally by the tenant or his deputy, nor to be performed to the person of the king, as the payment of rent in spurs, arrows, &c., the tenant was said to hold by *petit* or *petty* serjeanty, which was a socage tenure, having the same non-military incidents as a tenure upon which an annual rent in money, corn, &c., was reserved, though considered to be of a somewhat more dignified character.

The tenant in serjeanty was bound either to perform the special service himself, or to provide a person competent to discharge it. Sometimes, the land having descended to or been acquired by a citizen or a burgess, the service was considered of too great dignity to be performed by the tenant upon whom the duty of the serjeanty had thus devolved, in which case he was required to appoint a competent substitute. It happened more frequently, however, that the service to be performed was below the serjeant's rank, in which case it was permitted and expected that the service should be performed by deputy. This became so much a matter of course, that we find lands held in serjeanty commonly described as held by the service of procuring (per servicium inveniendi) persons to do the duty. This frequently happened with regard to the inferior offices relating to the administration of the law, as in the ordinary case of a tenure by the service of finding bailiffs itinerant. With respect to this particular appointment and some few others, the name itself was transferred from the appointer to the appointee, and the designation of serjeant was given to the person by whom the service of the serjeanty was actually performed. Hence our serjeants-at-mace, and other similar officers in Normandy and in England. In like manner, the sheriff being the ballivus of the county,—that is, the person into whose custody or bailiwick the county is *bailed* or delivered,—the inferior officers whom he employs have acquired the name of bailiffs. However humble the nature of the service may have been, the tenant was bound to perform it in person, in case no substitute could be obtained.

Among the civil services the performance of which was provided for by the creation of serjeanties, one of the most important was the administration of justice. Both in Normandy and in England numerous grants of lands were made, to which grants the obligation to discharge certain judicial or ministerial duties was annexed in lieu of the ordinary knight's service. In both countries it would appear that all counties, as well as the more important cities and boroughs, were placed under an officer of the crown who held lands by the tenure of administering justice in criminal matters. This local judge was in England called the king's serjeant (serviens regis), or the serjeant of the county, city, or borough; sometimes (stat. Westm. I., c. 30) serjeant in fee; sometimes capitalis serviens of the county ('Rot. Parl.,' 236) or of the hundred ('Testa de Nevil,' 409 d).

Lands held by this tenure are commonly described in ancient records as lands held per serjeantiam tenendi (sometimes custodiendi) placita coronæ. It appears from Bracton, fol. 157, that this officer (the king's serjeant) had a concurrent jurisdiction with the sheriff, and that their records were equally incapable of being controverted. These serjeants had officers under them, who, taking the denomination of serjeant from the hereditary officer whose authority was in part delegated to them, were in counties known by the name of serjeants of the sword, sergens de l'espee, servientes ad spatam, and in cities and boroughs by the name of serjeants-at-mace, servientes ad clavam. In the course of time, as charters were obtained, the citizens and burgesses acquired the right of choosing their own magistrates; and the king's officer, the serjeant, was superseded by the municipal officers, the mayor and aldermen. It is said that Norwich had no magistrate, except the king's serjeant, until the 17th year of King Stephen. (Stow, 214; Spelman, 'Gloss.') It sometimes happened that, after the incorporation of the city or town, the serjeant continued to be the judicial officer *de facto*, sitting as assessor to the municipal magistrates. This was the case at Oxford. ('Harleian MSS.,' 298, fol. 56.) In London the office appears to have been retained, but a charter of 12 Edw. II. gave to the citizens the privilege of electing their *common serjeant*.

In counties, the king's serjeant, as a judicial officer, may be traced to a much later period; and although the office is now become obsolete, and its principal functions have for centuries devolved upon the justices of the peace, proclamation is still made upon the execution of every commission of jail delivery, inviting all persons to inform this officer of any treason, felonies, or misdemeanors committed by the prisoner at the bar.

Where the criminal jurisdiction of a particular district was annexed to a grant of land to a subject, the jurisdiction, though imposed as a condition and a burden, was called a franchise [FRANCHISE], inasmuch as it excluded the ordinary power of the officers of the crown. The grantee was said to hold in frank serjeanty, en franche sergenterie; and in respect of the lands attached to the office, this serjeanty was in Normandy sometimes called une sergenterie glèbée. For the actual administration of justice, the tenant usually delegated his judicial authority as serjeant to an officer of his own, who was therefore called *his* serjeant, or the serjeant of the district (Mad. 'Exch.,' 103; 'Testa de Nevil,' 389), or serjeant of the peace for the district. (Cowell, 'Interpr.') Hence, the steward of a private leet, or of a manor to which a leet is attached, to whom the lord always delegates his judicial power, is sometimes designated as serviens sive senescallus. (4 Co., 'Rep.,' 21.) Latterly, indeed, it has been considered that a tenure by serjeanty could only be created by, and held under, the crown. (Co. Litt., 108 a.) This was not the case, however, in the time of Henry III., as appears by Bracton (35 b.).

The tenure, by which lands were held by a "serjeant of the county," or "serjeant in fee," was a serjeanty belonging to that class which was called grand serjeanty, as being connected with the administration of justice. Edmund, earl of Lancaster, brother of Edward I., died seised "de magna sergeantia totius comitatus de Derby." ('Calend. Inquis. post. mortem,' 136, b.)

But the serjeants of counties were neither the only nor the most numerous class of serjeants-at-law. The main branch of that body remained in attendance upon the king. Their duty was to assist in the proceedings of the Aula Regia, the great court of justice of the realm, as assessors to the chief justiciar, and as advocates for the suitors, who being generally unacquainted with the language in which the proceedings of the court were carried on, were seldom able, and were never permitted, to plead their own causes. (1 'Rot. Parl.,' 4 a; 2 'Rot. Parl.,' 140.) Upon the breaking-up of the Aula Regia into the several courts which now occupy Westminster Hall, the serjeants-at-law became the justices of the courts of King's Bench and Common Pleas, and acted as advocates for the suitors, when not appointed to those offices, and when removed from them. While not employed in judicial stations, they were called serjeant-countors, servientes-narratores, and banci narratores, countor (narrator) being a term derived from the Norman "conteurs," persons whose office it was to conduct the causes of litigants in court, the verb "conter" being applied indifferently to the pleadings on the part of the plaintiff and those on the part of the defendant.

It does not distinctly appear whether any grants of land were annexed to the office of serjeant-countor; if not, it is probable that the Conqueror, or some of his early successors, considered the fees receivable by the serjeant-justices and the serjeant-countors as equivalent to a grant of lands, and as constituting a serjeanty not attached to a tenure of land, or a serjeanty in gross. However this may be, the kings exercised the right of creating both serjeant-justices and serjeant-countors. The appointment of serjeant-countor has, from the earliest period, been effected by the royal mandate under the great seal; by writ, where the party to whom it was addressed was required to serve the king and his people in the Aula Regis, and afterwards in the courts of Westminster Hall; by letters-patent, with respect to serjeants in Ireland. Under this appointment, the serjeants were the sole public pleaders. They were the only persons in the state entrusted with the exercise of the ordinary judicial functions, and even now no person can be appointed a justice of the Queen's Bench or Common Pleas, who is not of the degree of the coif, that expression being derived from the peculiar species of cap which was, and still is, the distinguishing dress of serjeants-at-law. The barons of the Exchequer who were formerly merely officers of revenue, are not required to be taken from amongst the serjeants; but unless they were of the degree of the coif, they were not qualified to act as justices of assize. Although the serjeants on the circuit, and the queen's counsel, and occasionally other barristers, are included in the commissions of oyer and terminer, and jail delivery, and assist in the trying of prisoners when the judges are pressed for time, or if it is thought desirable to relieve the county from the expense arising from the detention of prosecutors and witnesses, the name of no person who is not a serjeant or queen's counsel, or possesses a patent of precedence, can be inserted in the commission of assize. Formerly no one but a serjeant was so qualified. (13 Edw. I. st. i., c 30; 13 & 14 Vict. c. 25.)

Much obscurity however still hangs over the origin of the connection between the terms serjeant and countor. It has been suggested that upon the introduction of the Norman conteurs in England, they were formed into a lay brotherhood, somewhat analogous in form to the religious communities by which they were surrounded; that the members of this brotherhood were admitted by royal authority, and employed in different capacities as judges and advocates about the Aula Regia; and that they probably derived their adjunct title of servientes from the nature of their employment, and from the circumstance of their appointment being conferred by the crown, and of its being considered that the services which they rendered were of equal dignity and importance with services reserved upon those tenures by grand serjeanty to which administration of justice was attached, and the tenants of which were in strict propriety denominated serjeants.

Upon the calling of every parliament, the judges and serjeants are summoned by writ to give their attendance. Their principal duty appears to have been to assist the lords in the trials of petitions. ('Rot. Parl.' *passim.*) The writ of summons issues to the judges, not as judges, but as serjeants; and if a baron of the Exchequer be not a serjeant, as was formerly often, and still may be, the case, he is not summoned. No serjeants have been required to attend of late years, except judges and queen's serjeants, but formerly other serjeants were also summoned.

Whilst the Aula Regis constituted one court, a second class of advocates was little needed; and upon that court being afterwards divided into different sections or branches, no inconvenience appears to have been felt, as all the different sections of the court equally followed the person of the king. But when, in the reign of Edward I., the regulation for holding common pleas, that is, all *civil* actions, in some certain place to be appointed by the crown, was put in force, parties who had business in the court of King's Bench, the jurisdiction of which, except occasionally as a court of appeal, was then almost confined to criminal matters, or in the court of Exchequer, the jurisdiction of which related to matters of revenue, or in the court of Chancery, were put to inconvenience for want of advocates, as often as the king, whose progresses these courts still followed, happened to be distant from the place (usually Westminster Hall, and seldom elsewhere, after the reign of Edward III.) at which the court of Common Pleas sat. To remedy this inconvenience, and at the same time to relieve parties from the burdensome duty of appearing in person in the court of Common Pleas, an ordinance was made in Parliament, in 1292, by Edward I., by which the king directed the selection of a number (fixed provisionally at 140) from the higher class of legal students to act both as attorneys in the stationary court of Common Pleas, and as advocates in the comparatively few cases which then required their assistance in the ambulatory courts of the King's Bench, Chancery, and Exchequer. No distinction is made in the ordinance between attorneys and apprentices, and the 140 appear to have acted indiscriminately (2 'Rot. Parl.', 96) as attorneys and as advocates, as their services happened to be required. Complaints were however still made in Parliament (1364-5) of the prejudice arising to parties implicated in proceedings in the two latter courts, from being unable to procure the assistance of serjeants; and it was prayed, though unsuccessfully, that on this ground these courts might also be made stationary.

A petition of the Commons in 1343, that parties to suits in the Marshalsea might be allowed to plead their own causes in that court, in order that they might not be delayed for want of serjeants, had met with a more favourable reception, and the permission was granted by an act of parliament (2 'Rot. Parl.,' 140), which act was not in print till the parliament rolls were published at the commencement of the present century. It was a punishable contempt of the court for a person to interfere as advocate without possessing a legal title to the office. ('Abb. Placit. in Dom. Cap. Westm.,' 137.)

It is stated in the article Barrister, that serjeants and apprentices at law were supposed by Dugdale to be the same persons. Dugdale relies upon the circumstance that in the second year of Henry VI. an apprentice was heard in the court of Common Pleas, where serjeants alone practised. But Dugdale was mistaken in supposing that the apprentice acted as an advocate in that court; for upon reference to the 'Year-Book' (M. 2 H. 6, fol. 5, pl. 3), it will be seen that this apprentice was merely sent by the Exchequer into the Common Pleas to ask the opinion of the judges and serjeants in the latter court upon a point of law then depending in the Exchequer; upon which the judges of the Common Pleas consulted the serjeants, and the point was debated by judges and serjeants indiscriminately. The apprentice took no part in the discussion, but carried back the result to the Exchequer, upon which that court acted. It has also been supposed that Plowden and Carrel, who are spoken of as apprentices in 4 Eliz., (1562), were at that time serjeants. With respect to the former, the mistake arose from the circumstance that a writ issued to Plowden and eleven others, in October, 1558, calling upon them to be made serjeants in Easter following. Mary dying in November, 1558, the writs abated. In 1559 fresh writs were issued by Elizabeth to seven of the eleven, but the names of Plowden and four others, as may be seen in Dugdale, were omitted. Plowden therefore remained an apprentice as before, and he is properly so designated in 4 Eliz. (1562). With respect to Carrel also, we have no distinct proof that he ever took the degree of serjeant, though it seems not improbable that he was often commanded so to do. John Carrel received a writ requiring him to take the degree of a serjeant in 1540, and again in 1552 and 1554. In what manner he was excused on these occasions, and whether he paid more attention to Mary's commands than he had done to those of her father and brother, or whether indeed the Carrel apprentice in 1562 was the same person with John Carrel, the serjeant thrice elect, does not appear.

The ordinance of Edward I. authorised only students who had reached the rank of "apprentices at law" to practise as advocates in those courts in which the assistance of serjeants could not constantly be obtained; but as the practice of these courts increased, it was found necessary, in the reign of Elizabeth, to allow persons of less standing than apprentices to act both as advocates and as attorneys.

Students who, though not yet apprentices at law, had been admitted to argue fictitious cases at the mootings in their respective inns of court, were allowed to practise as advocates in the ambulatory courts of common law and equity. Advocates of this third class were called utter-barristers, because in arguing their moot cases by way of preparation for real forensic debates they were placed at the outer or uttermost end of the form on which they sat, and which was called the "barr." (Stow; Waterhous; Dugdale; Herbert, 'Antiq. Inns of Court,' 176.) The junior students, who sat in silence on the inside, were called inner-barristers. But the latter term has long been abandoned, and is sunk in the more general designation of student; in consequence of which the term utter-barrister has also given place to that of barrister, and the student who is admitted to that degree is said to be "called to the bar." This call however consists merely in the presiding bencher's saying, "I publish you a barrister of this Society."

The mere students, formerly called inner-barristers, confine themselves to study, or, when they consider themselves qualified, practise as conveyancers, special pleaders, or equity draftsmen, in which capacity they are recognised by the legislature, being required to take out annual certificates from the stamp-office. For nearly the last forty years students practising as certificated special pleaders have been allowed to practise as advocates before judges sitting in their private chambers at Serjeants' Inn, for the summary despatch of matters of pleading and practice, &c.

Shortly after the permission given to barristers to practice as advocates, we lose sight of the order of apprentices. Though usual, it was never perhaps absolutely necessary that a student should become an apprentice in order to qualify him for being called to the degree of the coif; and when it ceased to be required as a title to practise as an advocate, there was no longer any motive for taking the degree of an apprentice.

The result of these inquiries seems to be, that from the Conquest to the 20 Edw. I. (1292), serjeant-countors were the only advocates; that from 1292 to the latter end of the 16th century, apprentices were allowed to practise in certain courts; that towards the close of the 16th century, the apprentices were supplanted by a more numerous class of junior students called utter-barristers and afterwards barristers; and that from the middle of the 18th century, mere students were at any time after their admission, and immediately upon their admission, allowed to practise as certificated conveyancers or certificated special pleaders; and that such special pleaders have latterly been allowed to practise as advocates before judges when administering justice in their private chambers; which latter practice may be thus explained:—The business to be disposed of by the courts at Westminster having far outgrown the machinery provided for its despatch, many acts of parliament have directed that certain judicial acts shall be done by the court "or any judge thereof." The consequence of these provisions, and of a practice existing before, of referring minor questions and cases of a pressing nature to be disposed of by a single judge, has been that a most important part of the judicial business of the country, instead of being discussed as formerly in open court before a full bench, and with the assistance or in the presence of an intelligent bar, is commonly disposed of by a single judge in a private room, without any assistance except that which he can derive from the attorney's clerks on each side who attend the summons. It not unfrequently happens that a most abstruse point of special pleading, involving the fate, and sometimes the real merits of the cause, and which in the reign of Edward VI. would have been argued by learned serjeants and *sad* apprentices at the bar, and afterwards debated publicly on the bench, is disposed of in five minutes, and without appeal, at chambers by a judge who has never practised this branch of the law, and who would when at the bar have shrunk from the responsibility of expressing an opinion on the most ordinary question connected with the science of special pleading. It was therefore quite natural that judges should be glad to avail themselves at chambers of the assistance of special pleaders; and in order to prevent the abuse of the indiscriminate invitation given by the legislature to all persons, though students only of a day's standing, who are members of an inn of court, to take out licences to practise as special pleaders, &c., the benchers or governing members of some of the inns of court now require that upon the admission of a student, he shall engage not to practise as a special pleader, &c., till he be of sufficient standing to be called to the bar.

The serjeants remained however, till 9 & 10 Vict. c. 54, the only advocates recognised in the court of Common Pleas. In that court they retained their right of exclusive audience, which privilege extended to trials at bar, but not to trials at nisi prius, either at the assizes or at the sittings in London and Middlesex.

Attempts had been made previously to place the court of Common Pleas upon the same footing in this respect as the other courts at Westminster. A suggestion to that effect was made by Sir Matthew Hale, in his 'Considerations touching the Amendments of the Law.' In 1755 it was proposed by Sir John Willes, then chief-justice of the Common Pleas, that the court should be opened to all barristers. The judges met, and, after much discussion, expressed their opinion against the plan, which was strongly opposed by Lord Hardwicke. It was nearly a century before effect was given to the enlightened views of Sir Matthew Hale and Sir John Willes.

In 1834, while the Central Criminal Court bill was in the House of Lords, a clause was introduced for opening the court of Common Pleas. This clause was withdrawn before the bill was sent to the Commons. But on 24th April, in that year, a royal warrant issued, ordering and directing that the right of practising, pleading, and audience in the court of Common Pleas should cease to be exercised exclusively by the serjeants-at-law, and that barristers-at-law should have and exercise equal right and privilege with them of practising, &c., in that court. The warrant professed to give to such of the serjeants then in practice as were not king's serjeants, and had not patents of precedence, *as an especial mark of royal favour*, precedence over any king's counsel who might be thereafter appointed. This warrant was filed in the court of Common Pleas on 25th April, from which time until January, 1840, it was acted upon by the court. During this period no persons applied for the coif, except those who had received an intimation that they were to be made judges.

In 1837, a petition was addressed to her majesty by the queen's serjeants and two other serjeants who had not availed themselves of the clause of precedence contained in the warrant of April 24, 1834, suggesting that the warrant was illegal, and praying that the legality of that document and the expediency of the alteration might be duly investigated. The illegality of the warrant was asserted chiefly upon the prescriptive rights of the serjeants, coeval with the existence of the courts themselves; but also on some merely technical grounds. A memorial was at the same time presented to the chancellor, in which it was submitted that such an alteration could only be made by act of parliament.

The petition being referred to the privy council, the question was argued on 10th January, 1839, and again on 2nd February. A strong opinion was expressed as to the illegality of the warrant, but the court separated without coming to any conclusion.

In November, 1839, a motion was made in the Common Pleas by Wilde, as the senior practising serjeant, that the exclusive right of audience of the serjeants-at-law, which had been suspended in obedience to the warrant of 1834, should be restored; and at the close of Hilary term, 1840, the right of being heard as counsel and of signing pleadings in causes depending in the Common Pleas, was declared by the court to belong exclusively to the serjeants-at-law. The legislature then took up the question seriously, and the monopoly of the serjeants was abolished by 9 & 10 Vict. c. 54.

Serjeants had formerly not only *exclusive audience* in the Common Pleas, but had also in all other courts *pre-audience* over all other advocates. They are still addressed by the judges as brothers, by which title they speak to and of one another.

Though the king was represented in each of his courts at Westminster by one or more persons as his attorney and solicitor-general in one or all of those courts, no one formerly pleaded as *counsel* for the crown except serjeants. In the patent of a king's serjeant, he was appointed by the king "Serviens Noster ad legem, et Narrator pro Nobis in curiis Nostris, in quibuscunque negotiis Nos tangentibus." Afterwards when the king's attorney, as it usually happened, was an apprentice, he was allowed not only to appear as attorney, but to plead as advocate for the crown in those courts in which apprentices were permitted to practise, and when so employed he claimed and exercised, for the benefit of the crown, a right of pre-audience over serjeants pleading for ordinary clients in those courts. Afterwards the attorney-general exercised a right of pre-audience even when not engaged for the crown.

Other king's counsel appear to have obtained pre-audience over the serjeants by a similar course of proceeding; but the queen's serjeants still retain pre-audience over all other counsel except the attorney-general and solicitor-general; and even over the attorney-general, the senior of the king's serjeants, distinguished by the appellation of "the king's ancient serjeant," retained his precedence until 1814, when Sir Samuel Shepherd, the king's ancient serjeant, being appointed solicitor-general, instead of vacating his office of serjeant, as had always before been done in such cases, obtained a warrant from the Prince-Regent giving to the attorney-general and solicitor-general perpetual pre-audience of the whole bar. In the reigns of Mary, Elizabeth, and James I., several persons were degraded, or discharged, from the degree of serjeant-at-law in order to capacitate them for accepting the office of solicitor-general, as it is not unusual now for barristers to apply to be disbarred for the purpose of enabling them to practise as solicitors or attorneys to private suitors.

The pre-audience acquired, in comparatively modern times, by the attorney-general and solicitor-general and the other king's counsel over the serjeants in the courts of Westminster Hall, has not otherwise affected the rank or position of the latter. At the coronation of Queen Elizabeth it appears to have been finally settled that in the royal procession (in which those of inferior rank walk first) "the attorney and solicitor-general walk immediately before the barons of the Exchequer, and immediately after the serjeants-at-law, who follow the knights-bannerets, bachelor-knights, masters of the chancery, clerks of the court, &c." (Egerton 'Papers,' 60.)

The serjeants formerly occupied three inns, or collegiate buildings, for practice, and for occasional residence, situate in Chancery Lane, Fleet Street, and Holborn. The last, called Scroop's Inn, has long been abandoned, and since the burning down of Serjeants' Inn, Fleet Street, in the middle of the last century, that site has also been deserted by the serjeants, who have now no other building than Serjeants' Inn, Chancery Lane. Here all the common-law judges have chambers, in which they dispose in a summary way, and with closed doors, of such matters as the legislature has expressly entrusted to a single judge, and of all business which is not thought of sufficient magnitude to be brought before more than one judge, or which is supposed to be of a nature too urgent to admit of postponement.

The inn contains, besides accommodations for the judges, chambers for fourteen serjeants, the junior serjeants while waiting for a vacancy being dispersed in the different inns of courts.

In Serjeants' Inn Hall the judges and serjeants, as members of the Society of Serjeants' Inn, dine together during term-time.

Formerly very splendid and expensive entertainments were given by the new serjeants upon their reception into the order. About a century ago this custom was discontinued, and instead of festivities at their joint expense, each serjeant paid 100*l.* to the Treasurer of the Society of Serjeants' Inn upon his admission as a member of that Society, into which the new serjeants are elected almost as a matter of course. The payment is now raised to 350*l.* The practice of giving gold rings to the queen and the great officers of state and others still continues, though the number has been lately reduced. These rings, with the robes and other expenses, raise the 350*l.* to something less than 500*l.* The peculiar dress of the serjeants-at-law, besides their distinctive coif, consists in four species of robes. In term time the gown of black cloth is worn on ordinary occasions. On holidays the serjeants appear in court in purple (violet coloured) gowns. When they go in state to St. Paul's, they wear scarlet gowns, as also when they attend the House of Lords, if the sovereign be present, and when they dine at Guildhall on lord mayor's day. At nisi prius they appear in black silk gowns, which, as being at hand, they generally wear when called upon to try causes or prisoners on the circuit, though for the latter purpose the scarlet gown, always accompanied with a *sentence cap*, is understood to be the appropriate costume.

The creation of serjeants was anciently attended with numerous ceremonies, a description of which may be seen in the last chapter of Herbert's 'History of Inns of Court.' Some practices belonging to an age of greater simplicity than the present, are still retained in those cases where the writ to the serjeant elect issues *in term-time*. But by 6 Geo. IV., cap. 95, persons receiving writs, issued *in vacation*, commanding them to appear in the Court of Chancery and to take upon themselves the estate and dignity of a serjeant-at-law, are, upon appearing before the lord chancellor and taking the oaths usually administered to persons called to that degree and office, declared to be serjeants-at-law sworn, without any further ceremony.

Another class of serjeants is that of serjeants-at-arms, whose number is limited, by statute 13 Rich. II., cap. 6, to thirty. Their office is to attend the person of the king, to arrest offenders, and to attend the lord high steward when sitting in judgment upon a peer. Two of these serjeants-at-arms by the king's permission attend the two houses of parliament. In the House of Commons, the office of the serjeant-at-arms (as he is emphatically called) is to keep the doors of the house, and to execute such commands, especially touching the apprehension of any offenders against the privileges of the Commons, as the house through its Speaker may enjoin. From these serjeants-at-arms the present regimental serjeants are probably derived.

In some offices about the royal person the principal officer of the department is distinguished by the appellation of serjeant, as the serjeant-surgeon, serjeant-painter, &c.

Many of the documents referred to in the present article are printed at length in the Appendix to Manning's 'Serviens ad Legem,' which is a report of the argument before the Privy Council in 1839.

Serjeants and other counsel are engaged to assist a party in a cause either by the delivery of a brief in that cause or by giving a retainer or retaining fee. A retainer, if for a particular cause, or for a particular stage of that cause, is called a common retainer, and it now consists in the payment of the sum of one guinea and the delivering of a paper endorsed with the name of the cause and of the court, and the words "Mr. Serjeant A (or 'Mr. B'), retainer for the plaintiff" (or for the defendant). A general retainer is where a retaining fee of five guineas is given to counsel to engage the assistance of that counsel in all causes in which the party retaining may be concerned in the courts which the counsel retained attends. A special retainer is where a large fee is given to counsel to plead in a particular cause on a circuit on which he does not usually practise. This fee is given and received partly with a view to remunerate the counsel for the inconvenience of leaving other engagements to come to a strange circuit, and partly for the purpose of preventing any unnecessary interference with the business of the regular practitioners of the particular court into which he is brought, in cases which are not of great importance. Both the common and the special retainer amount to an engagement on the part of the counsel to accept the brief of the party retaining, and to refuse any brief offered by the adverse party, and on the part of the client, to deliver a brief to the counsel retained in case the cause is entered for trial, whether a trial takes place or not. A general retainer merely renders it imperative on the counsel retained to accept no brief or retainer from the adversary of the party retaining, until he has first ascertained that it is not the intention of the latter to require his services in the particular cause. The general retainer continues in force during the joint lives of the retaining client and the counsel retained, unless the engagement be cancelled by the former, who is at liberty at any time to renounce his title to the services of the counsel retained. In the case of a common or a special retainer, the contract can be put an end to only by the concurrent act of counsel and client.

In cases of importance, counsel are generally retained before the action is actually commenced; and it often happens that for want of sufficient information as to the form of the intended proceedings, or from carelessness, the cause is not described in the retainer with sufficient accuracy. When this is the case, the retainer is void, and the counsel is bound to accept the retainer of the adverse party, if tendered before the mistake has been corrected. The sufficiency of the first retainer becomes frequently the subject of dispute between the litigant parties, which dispute, if not arranged between themselves, is generally settled not by the counsel to whom the retainer is given, but by some other leading counsel.

In former times it was usual, particularly for great persons and public bodies, especially for religious corporations, to grant annuities pro consilio impenso vel impendendo.

SERJEANT, or SERGEANT, is a non-commissioned officer in a troop of cavalry or in a company of infantry. The duties of serjeants are to drill or instruct in discipline the recruits of a regiment; to look after the interior economy and discipline of the troop or company under the captain and subalterns; whilst on parade they act as markers or guides in the performance of the evolutions. The serjeants of infantry are now armed with muskets like the rest of the troops. In each company, when a battalion is in line, a covering serjeant is always stationed behind the officer commanding the company; when the ranks take open order, and that officer advances before the front rank, the serjeant steps into his place; but upon the ranks being closed, he falls again to the rear. Four or six serjeants are charged with the duty of guarding the colours of the regiment: they constantly attend the officers who carry them, and are called colour-serjeants. One serjeant in each troop or company is appointed to pay the men; also to keep the accounts relating to their allowances, the state of their necessaries, &c. There are five serjeants, including the colour-serjeant, to each company.

The name of sergens or servientes was, in the armies of France during the reign of Philip Augustus, applied to gentlemen who served on horseback, but were below the rank of knights; and also, as a general term, to the infantry soldiers who were furnished by the towns. There was, besides, a body of troops consisting of 150 or 200 men of rank, who were called sergens d'armes, and were instituted by the prince just mentioned for his protection, when in the East, against the subjects of the chief of the Assassins. (P. Daniel, 'Hist. de la Milice Fr.,' liv. iii. ch. 7, and liv. ix. ch. 12.)

Corresponding to this corps was the body of serjeants-at-arms, which was instituted in England by Richard I., and appointed to guard the royal tent in complete armour. At first it consisted of twenty-four men, but the number was afterwards increased. Being accused of extortion and oppression, the parliament made several applications to the king that their number might be diminished, and in the reign of Edward IV. the desired reduction took place. (Grose, 'Mil. Antiq.,' vol. i. p. 199.)

In the reign of Philip and Mary the serjeant-major of the army was an officer whose post corresponded to that of the modern major-general; and the serjeant-major of a regiment was a field-officer, who would now be designated the major. At present the serjeant-major is an assistant to the adjutant, and keeps the roster for the duties of the serjeants, corporals, and privates. The quartermaster-serjeant is one who acts immediately under the quartermaster of a regiment in all the details relating to the quarters of the officers and men, the supplies of food, clothing, &c.

SERJEANT-AT-ARMS. [SERJEANT. (Law.)]
SERJEANT-AT-MACE. [SERJEANT. (Law.)]
SERJEANTY. [SERJEANT. (Law.)]

SERMON, a form of the Latin *sermo*, which denotes a discourse of any kind, and even common talk or conversation. It is now however applied only to a discourse of a particular kind, namely, one delivered to an assembly of persons who are gathered together for purposes of devotion, or in the character of a Christian and religious congregation. Nor is any address delivered on such occasions properly a sermon, though the word is very loosely used, and addresses delivered on such occasions, which can hardly be called sermons, are not unfrequently so denominated; but it seems to be essential to a sermon that it shall be a discourse grounded on some particular passage of holy Scripture which more or less influences the preacher in the whole of his discourse. This passage is called the *text*, that is, it is the portion of the *text of Scripture*, of which the sermon is the long paraphrase and commentary, with suitable application and exhortation intermixed or appended.

The sermons delivered in the English church before the Reformation were very short, probably seldom requiring more than ten minutes for the delivery of them. Many specimens remain in manuscript, but few are generally accessible by having been printed. Perhaps the most remarkable and the most easily consulted are the sermons at the opening of each parliament, of which there are notices in the printed rolls.

But with the Reformation a great change in this respect took place; and in many cases the ministers of religion came to consider themselves rather as persons whose peculiar duty it was to exhort and preach, than to conduct the devotions of a Christian assembly and to minister the sacraments. The consequence of this was that the sermons ran out to a great length, and assemblies were gathered together rather for the purpose of listening to them than of entering into the devotions of the church; and the term "preaching minister" was invented to designate those ministers who changed the nature of their office, from one which was instituted for the administration of the

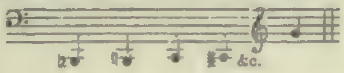
Christian ordinance and the assisting the people in their devotions, to one which was of teaching, if not exclusively, yet principally. It was not very unusual in the 17th century for congregations to listen to sermons which occupied one, two, or even three hours in the delivery. Many of these sermons are in print, and may therefore be now read and judged of.

There is a singular work by a minister of the French Reformed church at Charenton, Monsieur Claude, entitled 'An Essay on the Composition of a Sermon.' This was translated by Robert Robinson, a Baptist minister at Cambridge, who has illustrated the rules by numerous quotations from English sermon writers. This translation is in two volumes, 8vo., 1779.

SERPENS (the Serpent), a constellation which is astronomically distinguished from OPHIUCHUS, but not mythologically, being the serpent carried by the Serpent-bearer. The windings of the figure bring it in contact with Aquila, Ophiuchus, Libra, and Hercules.

Character.	No. in Catalogue of Flamsteed.	No. in Catalogue of British Association.	Magnitude.
δ	13	5135	3
α	24	5196	2
λ	27	5214	4
β	28	5216	3
μ	32	5230	4
ε	37	5245	3
γ	41	5284	3
π	44	5322	4
ν	53	5845	4
ξ	55	5949	4
η	58	6229	3
θ^1	63	6460	3

SERPENT, a musical instrument, a long conical tube of wood covered with leather, having a mouth-piece, ventages, and keys, and bent in a serpentine form; hence its name. The compass of the serpent is from B flat below the base staff, to G, the treble clef line, including every tone and semitone between these extremes. Or—



The use of this is confined to military bands, though it might have been rendered valuable in the orchestra. The ophecleide however, an instrument applicable to the same purposes, but of far superior utility, has already obtained a place in the concert-room, and will, probably, supersede altogether its ancient and imperfect precursor. [OPHICLEIDE.]

SERPENTARIN. Synonymous with ARISTOLOCHIN.

SERVANT, one who has contracted to serve another. The person whom he has contracted to serve is styled master. Servants are of various kinds; apprentices [APPRENTICE], menial or domestic servants who reside within the house of the master, servants in husbandry, workmen or artificers, and clerks, warehousemen, &c. From the relation of master and servant a variety of rights and duties arise. Some of these are founded on the common law, and some on special statutory enactments.

A contract of hiring and service need not be in writing unless it be for a period longer than a year, or for a year to commence at some future time. If in writing, it is not liable to any stamp duty, unless it apply to the superior classes of clerks, &c. To all such contracts the law attaches an implied undertaking on the part of the servant faithfully and carefully to serve the master, and to do his lawful and reasonable commands within the scope of the employment contracted for; on the part of the master, to protect and fairly remunerate the servant. This implied undertaking to remunerate may be rebutted by circumstances showing that it never was contemplated, as where it appears that the servant merely came on trial, or where a party has brought to England a person who was his slave abroad. In all hirings where no time of duration is expressed, except those of menial servants, it is a rule of law that the contract shall continue for a year. In the case of menial servants it is determinable by a month's warning, or the payment of a month's wages. Servants in husbandry can only be discharged or quit the service upon a quarter's notice. This rule as to time may of course also be rebutted by any circumstances in the contract inconsistent with its existence. In the case of immorality, or any kind of offence amounting to a misdemeanor committed during the time of the service, or of continued neglect, or determined disobedience, a servant may be immediately discharged; and the service having been determined before the expiration of the time contracted for, in consequence of the fault of the servant, he is not entitled to claim wages for any portion of the time during which he has served. The contract continues to exist, notwithstanding the disability of the servant to perform his duties from illness, and he is in such a case entitled to receive his wages. The master however is not bound to pay the charges incurred by medicine or attendance upon his sick servant. In case the goods of the master are lost or broken by the carelessness of the servant, the master is not entitled to deduct their value from the wages of the servant, unless there has been a special contract between them to that effect. His only remedy is by an action. Where a master becomes bankrupt, the commissioners are authorised, on proof that they are due, to pay six months' wages to his clerks and servants. If the wages for any longer period are due, they must be proved for like other debts under the fiat. If a servant has left his service for a considerable time without making any demand for wages, it will be presumed that they are paid. A master may chastise his apprentice for neglect or misconduct, but he will not be justified in striking any other description of servant. Servants who steal or embezzle their master's goods are subject to a greater degree of punishment than others who commit those crimes. [LARCENY.] Masters are not compellable to give a character to servants who leave their employment. If they choose to do so, and they give one which is false, they may be liable to an action at the suit of the servant; but in order to recover in such an action, the servant must prove that the character was maliciously given for the purpose of injuring him. If the master, merely for the purpose of confidentially communicating, *bonâ fide* state what he believes to be the truth respecting a servant, he is not responsible for the consequences of his communication.

By a great variety of statutes, a special jurisdiction is given to magistrates over servants in husbandry, and also in many classes of manufactures and other employments. None of these rules of law apply to menial servants. The object of them, as relates to servants in husbandry, is to compel persons not having any ostensible means of subsistence, to enter into service, to regulate the time and mode of their service, to punish negligence and refusal to serve, to determine disputes between masters and servants, to enable servants to recover their wages, and to authorise magistrates under certain circumstances to put an end to the service.

Those statutes which relate to servants in manufactures and other employments prohibit the payment of wages in goods, and provide for their payment in money, and for the regulation of disputes concerning them. They also contain various enactments applicable to the cases of workmen, &c., absconding, neglecting or mismanaging their work, injuring or embezzling the materials, tools, &c., entrusted to them, and fraudulently receiving those entrusted to others. With respect also to this class of servants, magistrates have authority to put an end to the contracts of hiring and service.

By reason of the relationship which exists between a master and a servant, and the protection which is thereby due from the former to the latter, a master is not held to be guilty of the offence of maintenance [MAINTENANCE], though he maintain and support his servant in an action brought by him against a third party. When a servant is assaulted, his master is justified in assisting his servant, and repelling the assault by force, although he himself be not attacked; and under similar circumstances a servant may justify an assault committed in defence of his master. A master is answerable, both civilly and criminally, for those acts of his servant which are done within the scope of his employment. Thus a master is indictable if a servant commit a nuisance by throwing dirt on the highway; and a bookseller or newsvender is liable, criminally as well as civilly, for libels which are sold by his servant in his shop. This liability of the master does not release the servant from his own liability to punishment for the same offence. The servant is also liable when he commits a trespass by the command of his master. A master, although liable civilly for any injuries arising from the negligence or unskilfulness of his servant, is not responsible for the consequences of a wilful act of his servant done without the direction or assent of the master: in such case the servant alone is liable. Where a servant makes a contract within the scope of his employment, what he does will be binding on his master, just as if he had expressly authorised the servant. But in all cases where there is no express evidence of the delegation of the master's authority, there must be facts from which such delegation can be inferred. Where a servant obtains goods for his master, which the master uses, and he afterwards gives money to the servant to pay for them, the master will be liable to pay for them, even though the money should have been embezzled by the servant. If a coachman go in his master's livery to hire horses, which his master afterwards uses, the master will be liable to pay for them, though the coachman has received a large salary for the express purpose of providing horses; unless, indeed, that fact were known to the party who let out the horses. If a master is in the habit of paying ready money for articles furnished to his family, and gives money to a servant, on a particular occasion, for the purpose of paying for the articles which he is sent to procure, the master will not be liable to the tradesman if the servant should embezzle the money. Where articles furnished to a certain amount have always been paid for in ready money, and a tradesman allows other articles of the same character to be delivered without payment, the master will not be liable, unless the tradesman ascertains that the articles are for the master's own use. Where a tradesman, who had not before been employed by a master, was directed by a servant to do some work, and afterwards did it without any communication with the master, it was held that the master was not liable, though the thing upon which the work was done was the property of the master.

By the contract of hiring and service, the master obtains a right to the service of the servant. Any one, therefore, who interferes with that right does him an injury for which he is responsible in an action for damages. A master may be deprived of the services of a servant, either by some hurt done to the servant, or by his being enticed out of the service. An action, therefore, may be brought by a master where a servant has received some personal injury disqualifying him from the discharge of his duties as a servant, as where he has been disabled by the overturn of a coach, the bite of a third person's dog, &c. The action by a parent against the seducer of his daughter is of this class, and purports to be brought to recover the damages incurred by the parent for the loss of his daughter's services; and although in practice the damages are never really measured by the injury occurring from the mere loss of service, still, from the form of the action,—the only one which can be brought in such a case,—it is necessary to give evidence of services performed. Any kind of assistance in domestic offices is sufficient. [PARENT AND CHILD.]

In order to succeed in an action for enticing a servant out of his service, the master must prove that the party enticing away the servant knew of the previous engagement at the time when he enticed him away, or that he has refused to restore the servant upon subsequent application. This action is maintainable where the servant is hired to do work by the piece, as well as where the servant is hired for a definite time. But no action lies for inducing a servant to quit his service at the period when the definite time for which he was hired expires, although the servant had no previous intention of quitting the service at such period. Neither will an action lie against a party for enticing away a servant if the servant has paid to the master the penalty stipulated for by the agreement of hiring and service in case of his quitting his master's service. Where a servant has been enticed away from the service, an action lies against him for his breach of contract, as well as against the party who has enticed him away.

It is not inconsistent with the duty of the servant of a tradesman to solicit his master's customers to give him business after he shall have left the service of his master. Where a workman discovers a new invention during the time of his service, the invention is the property of the servant, unless perhaps he were specially hired for the purpose of making new inventions.

Penalties are imposed by the statute law upon parties who personate masters and give false characters with servants; and also upon those who, though they really have been masters, wilfully make false statements in writing, as to the time and particulars of the service or the character of the servant, and also upon those who personate servants or falsely state that they have been in particular services, or deny that they have been in such employments as they really have filled. A person who wilfully gives a false character with a servant is also liable to an action at the suit of the party who has been induced by the false character to employ the servant, for any damages which he may suffer in consequence of employing him. Thus, where one was induced by a false character to employ a servant who afterwards robbed him to a large amount, and was convicted of the robbery, the master was held to be entitled to recover to the extent of his loss from the party who gave the false character.

Formerly a settlement was gained by residence in a parish under a contract of hiring and service for a year; but no settlement can now be gained by such means.

SERVICE (Law). [SERVANT.]

SERVICE, the name given in English cathedral music to the *Te Deum* and *Jubilate*, the *Magnificat* and *Nunc Dimittis*, the *Cantate Domino* and *Deus Misereatur*, collectively or separately; and sometimes applied, very erroneously, in our concert books, to the whole or portions of the mass.

SERVITES, or Servants of the Blessed Virgin, a religious order first instituted in Tuscany, A.D. 1233, by seven Florentine merchants. This order, though subjected to the rule of St. Augustine, was nevertheless erected in commemoration of the most holy widowhood of the blessed Virgin, for which reason its monks wore a black habit, and observed several rules not practised in other monasteries.

Toward the close of the 16th century it was found that the Servites had fallen off from their early strictness; and in 1593 the order was re-established in its original austerity in the hermitages of Monte-Senario, where the reformed brothers took the title of *Servites-Eremites*. This order continues to exist in Italy.

Father Paul Sarpi, the well-known author of the 'History of the Council of Trent,' was a Servite.

(Mosheim, *Eccles. Hist.*, Cent. xiii. Part ii. s. 20; *Hist. des Ordres Religieux*, par M. Henrion, 8vo. Brux., 1838.)

SERVITOR. [SIZAR.]

SERVITUDE, PENAL. [PENAL SERVITUDE.]

SERVITUDES (*servitutes*). A servitus in the Roman law signifies that the owner of some particular property is bound in respect to some other person, simply as such person, or as being the owner of a particular property, either not to do certain acts to his property, or to allow that other person to do some particular acts to the property.

Servitutes were thus either a right belonging to some particular person, which ceased with his life (unless they were granted to him and his heirs), and were called servitutes personarum or personales; or they were attached to a piece of ground as the subject, and could be exercised by any person who was in the possession of the ground, and were called Jura, or servitutes prædiorum or rerum, and sometimes Servitutes simply. Personal servitudes were comprehended under the heads of Ususfructus, Usus, Habitatio (a lodging in another person's house), and Operæ Servorum et Animalium (the use of another person's slaves or beasts).

Prædial Servitudes were either Servitutes Urbanæ or Rusticæ. They were Urbanæ if the property which was entitled to the servitude was a building; they were Rusticæ if it was a piece of ground. There was no limit to the number or kind of servitudes of this class which might be established. Those Servitutes Urbanæ which were of ordinary occurrence were such as follow:—Servitutes oneris ferendi, the right which a man has to let his building rest on the building, the wall, or the pillar which belongs to another; Tigni immittendi, the right of fixing a man's timbers in his neighbour's wall; Luminum, sive luminis excipiendi, the right of a man's making windows or openings in his neighbour's wall, or in a common wall, in order to get light for his own building, or to make holes or windows in a man's own wall, which holes or windows look into his neighbour's property, in such cases as would be unlawful without the existence of the servitude; Ne luminibus officiatur, the right to prevent a neighbour from obstructing the light that comes to a man's buildings, by raising any obstacle in the way; and others of a like kind. The Servitutes Rusticæ were rights of road over another man's property, which were of various kinds according to the kind of road, as Servitus itineris, actus, viæ; Pascendi sive pascui, right of pasturing a man's animals on another man's ground; and the various servitudes which have for their object the use of water, as servitus aquæ ductus, aquæ haustus, and others of a like kind.

Servitudes might be established by contract, by testamentary disposition, by prescription in the Roman sense, and in some other ways. They might cease by the party entitled to them renouncing them by express words or tacitly: in the case of prædial servitude, by one person becoming owner of the servient and dominant properties; and in some other ways.

The prædial servitudes may be compared with some of the easements and rights of the English system. The personal servitudes of the Roman law do not correspond, except in some few cases, with anything in the English law, except limited enjoyments of a thing, as, for instance, an estate in lands for life.

The subject of the Roman servitudes would require a long exposition to be treated fully. A good outline is contained in Thibaut, 'System des Pandekten Rechts,' i. § 296, &c., 9th ed.; and in Mackeldey, 'Lehrbuch,' &c., ii. § 274, 12th ed.

SESQUIALTER, the name of a stop on the organ, containing three ranks of pipes, thus giving three pipes to each organ key, which are tuned in different but harmonic intervals. Sometimes the *Mixture* stop is considered as part of the Sesquialter, in which case the latter is said to contain five ranks of pipes, all tuned in harmonic intervals. [ORGAN.]

SESSION, COURT OF, is the principal tribunal of civil jurisdiction in Scotland. As at present constituted, it dates back to the year 1532, but it was then reconstructed on the basis of institutions which had existed at a much earlier period. The early records of the Scottish Parliament show that the judicial authority, which in those times was mixed with the legislative functions of that body, was often deputed to committees. These were termed Domini Auditores, or Domini ad Querelas, and received other like titles. We find these committees and their functions placed on a more distinct position in 1503, when a permanent body received the designation of "The Daily Council." It is worthy of observation that these incidents in the history of the court explain the absence of jury trial as a fundamental feature in the Court of Session, while in early times it is known to have belonged to the courts of the inferior judges. Parliament being the high jury of the nation, it would be an anomaly that a committee of that body should act through the aid of a jury. The number of the court as finally established in 1532 was fifteen, the usual number of a Scottish jury in former times, and still the number of a jury in a criminal prosecution. There was then a lord chancellor of Scotland, whose functions in some degree resembled those of the same official in England. He presided over the Court of Session, and his judicial functions gradually came to be absorbed in those of the court. At the union with England it was deemed unnecessary to retain a separate chancellor of Scotland, and the great seal to be appended to private documents for that part of the country being committed to a keeper, the court was presided over by the lord president, who previously presided in the absence of the chancellor. In 1808 the Court of Session was divided into two divisions: the head of the court, the lord president (who is also now lord justice-general or head of the supreme criminal court) presides in the first division, and the lord justice clerk in the second. In 1815 trial by jury in civil cases was introduced in Scotland, a separate tribunal being established for these cases; but in 1830 the practice of jury trial was united with that of the Court of Session. It is still only adopted in a limited number of cases, and is far from being popular or satisfactory. The Scottish mode of pleading is ill adapted to it, and no means have been found, or indeed tried, of carrying it through with the promptitude and precision which mark the English practice. In 1830 two separate courts of limited jurisdiction and small practice—the Admiralty and Commissionary Courts—were absorbed in the Court of Session, and the number of judges was at the same time reduced from fifteen to thirteen. Eight of these judges, formed into two courts of four judges each, sit in the two divisions of the Inner House, where each division forms a court of second instance. The five other judges are called the Lords Ordinary, and each of them holds a separate court, which, in reference to the court of further resort, is called the "Outer House." The judgment of a lord ordinary on a closed record is final in the Outer House, but it may, within a limited time, be carried by a "reclaiming note" to which the record is appended, to the Inner House, where it may be pleaded again on the record as made up in the Outer House.

The jurisdiction of the Court of Session embraces all questions of civil right. It gives remedy when other courts whose function it is to regulate the rights and duties of certain sections of the public as members of a particular class—such as courts martial and ecclesiastical—exceed their powers. The proceedings before the Court of Session in relation to the church courts were the cause of the great secession from the Scottish Church in 1843. As every description of civil question between man and man in Scotland can be competently decided before the Court of Session, it is usual in England to speak of it as a court "both of law and equity;" but this is a distinction proceeding from incidental circumstances in the character of the English courts, and is no necessary or properly systematic division of the administration of the law. The Court of Session has the authority enjoyed by the equity courts in England, in the appointment of guardians, receivers, &c., or otherwise seeing to the protection of property, or of persons where discretional protection or direction are necessary, and there is no person competent in ordinary course of law to act. It has also the same authority as the Court of Exchequer in matters of revenue. By an old practice in Scotland, each "Senator of the College of Justice," as the judges of the Court of Session are officially called, takes the title of lord.

SESSION, KIRK, is the lowest judicatory in the system of the Church of Scotland, having jurisdiction only over a single parish. There is, or ought to be, a kirk session in every parish, composed of the minister, who is *ex officio* moderator or chairman, and of the lay elders, who must be at the least two in number. The moderator has only a casting vote. Meetings of the kirk session may be called at any time by the minister; but they are commonly held at stated intervals, and it is not unusual for the session to meet on the Sunday after service. It would rather appear from the 'First Book of Discipline' that the nomination or election of elders was originally in the congregation; but the modern practice is for the session to supply vacancies in, and to make additions to, its number by its own selection, only submitting the names to the congregation, that any objections may be made and inquired into by it; and in cases where there happens to be no session in existence, one is appointed by the presbytery. In some of the largest town parishes there are as many as fifty or sixty elders; but in most cases the number does not exceed five or six. In country parishes the elders, or at least those of them who do the duties of the office, are commonly respectable tradesmen, shopkeepers, or mechanics, although persons of higher station occasionally get themselves appointed, principally with a view to qualifying themselves for seats in the General Assembly or the other church courts. The law however is, that an elder must be resident in the parish at least six weeks in the year. He is elected for life, or so long as he remains qualified to hold the office. Every kirk session is represented by an elder both in the presbytery and the synod; the same member being deputed to both courts, and holding his commission for six months. The elders sent to the Assembly, like the other members of that supreme court (except the representatives of the royal burghs and the universities), are nominated by the presbytery. The kirk session may be regarded as the council of the minister, who, strictly speaking, is scarcely authorised to perform any act in the administration of the spiritual affairs of the parish, beyond officiating in the services of the kirk, without the concurrence of his elders. In practice, however, the clergyman very rarely encounters any opposition in the kirk session. The ordinary business of the session is to exercise spiritual discipline within the parish, by inquiring into scandals, and punishing delinquencies, which is done by suspension from the benefit of church ordinances, by public or private rebuke, and by pecuniary fines (exacted of course, like submission to the other penalties, only as the price of restoration to communion with the church, for the session has no power to force any person even to appear on its summons). The evidence in all cases that come before the session (at least after the inquiry has fairly commenced) is taken upon oath, and is, or ought to be, carefully recorded by the session-clerk, who is a paid officer, not necessarily a member of the court. There is in most cases an appeal from the judgment of the kirk session to the presbytery; and some graver offences can only be tried by the presbytery even in the first instance. The distribution of the ordinary collections made at the church door for the support of the poor, is also in the hands of the kirk session; and the management of all other funds and assessments allotted to the same purpose is conjointly in that body and in the heritors or landed proprietors of the parish. In the non-established Presbyterian bodies the lay-members of the kirk-session are appointed by the direct vote, or with the consent of the members of the congregation. The duty of the session, of which the minister is moderator, is to attend to the spiritual discipline of the body, and to care for the

poor. A body of *managers* is generally chosen at an annual business meeting of the members of the congregation, whose duty is to transact the secular business, such as collecting seat-rents, paying the minister's stipend, &c. In the Free Church of Scotland, *deacons* are usually appointed, who in conjunction with the elders, constitute the *deacons' court* , for the management of the secular affairs of the congregation.

(Principal Hill's *View of the Constitution of the Church of Scotland*; Dr. Alexander Hill's *Practice in the several Judicatories of the Church of Scotland.*)

SESSIONS. A session is the period during which any court of law sits for the transaction of judicial business; but the term Sessions is commonly used to denote the meeting of the justices of a county, or other district which has a separate commission of the peace, for the execution of the authorities conferred by the crown by that commission and others created by act of parliament.

County Sessions.—The commission of the peace issued by the crown for the purpose of creating county magistrates, consists of two branches. The former, relating to the powers to be exercised by justices individually and separately, has been already set forth. [JUSTICES.] The second branch of the commission creates the powers of the justices when assembled in sessions, and contains the quorum clause, so called because when the commission was in Latin, the clause ran "*quorum* A.B. vel C.D. vel E. F., &c. unum esse volumus."

The statute 1 Mary, sess. 2, c. 8, s. 2, prohibits sheriffs from exercising the office of justice of the peace during the time that they act as sheriffs. They might otherwise be called upon to act in the same matter both as judges and officers,—to execute, as sheriffs, precepts which they had issued as justices. It has been supposed that where a justice is elected coroner, he is discharged of his authority of justice. But if he be created a duke, archbishop, marquess, earl, viscount, baron, bishop, knight, judge, or serjeant-at-law, his authority as justice of the peace remains. (1 Edw. VI. c. 7.) By 5 Geo. II. c. 18, s. 2, attorneys, solicitors, and proctors are prohibited from acting as justices of the peace for any county during the time that they continue in practice.

A meeting of the justices held for the purpose of acting judicially for the whole district comprised within their commission constitutes a court of general session of the peace. By 12 Rich. II. c. 10, sessions are required to be held in every quarter of the year, or oftener if need be. The four sessions so held are styled courts of general quarter-session of the peace, or, in common parlance, "quarter-sessions." By different statutes the quarter-sessions are directed to be held at uniform periods. The times at which they are directed to be held are, the first week after the 11th of October, the first week after the 28th of December, the first week after the 31st of March, the first week after the 24th of June. Though the justices act irregularly in omitting to convene the quarter-sessions at the prescribed periods (except the April sessions, in respect of which power is expressly given to the justices to alter the time to any day between the 7th of March and the 22nd of April), sessions held as quarter-sessions in other periods of the quarter are legal quarter-sessions. When the business to be transacted at a court of quarter-sessions is not completed before the time at which it is thought desirable for the justices to separate, the court is usually adjourned to a subsequent day; so where there is reason to expect that new matters will arise which it will be desirable to dispose of before the next quarter-sessions. Two justices, one of them being of the quorum, may at any time convene a general session of the peace; but at such additional session no business can be transacted which is directed by any act of parliament to be transacted at quarter-sessions.

Both general sessions and general quarter-sessions are held by virtue of a precept under the hands of two justices, requiring the sheriff to return a grand jury before them and their fellow-justices at a day certain, not less than fifteen days after the date of the precept, at a certain place within the district to which the commission extends, and to summon all coroners, keepers of jails and houses of correction, high constables, and bailiffs of liberties [FRANCHISE] within the county.

Persons bound to attend at the sessions are, first, all justices of the peace for the county or district; secondly, the custos rotulorum of the county, who is bound to attend by himself or his deputy, with the rolls of the sessions; thirdly, the sheriff by himself or his under-sheriff, to return the precept and lists of persons liable to serve on the grand or petty jury, to execute process, &c.; fourthly, the several coroners of the county or district; fifthly, the constables of hundreds or high constables; sixthly, all bailiffs of hundreds and liberties; seventhly, the keepers of jails, to bring and receive prisoners; eighthly, the keeper of the house of correction, to give in a calendar and account of persons in his custody; ninthly, all persons returned by the sheriff as jurors; tenthly, all persons who have entered into a recognisance to answer charges to be made against them, or to prosecute or give evidence upon charges against others.

Persons summoned on grand or petty juries ought to be males between 21 and 60 years of age, who are possessed of 10*l*. a year in lands or rents, or 20*l*. a year in leaseholds for an unexpired term or terms of 21 years or more, or who are householders, rated to the poor on a value of not less than 20*l*. (in Middlesex 30*l*.), or who occupy houses containing not less than 15 windows, and who are not peers, judges of the superior courts, clergymen, Roman Catholic priests, dissenting ministers following no secular employment but that of schoolmaster, serjeants or barristers-at-law, doctors or advocates of civil law actually practising, officers of courts actually exercising the duties of their respective offices, coroners, jailers or keepers of houses of correction, members or licentiates of the College of Physicians actually practising, members of the Royal Colleges of Surgeons in London, Edinburgh, or Dublin, and actually practising, certificated apothecaries actually practising, officers in the army or navy in full pay, pilots licensed by the Trinity House, masters of vessels in the Buoy and Light service, pilots licensed by the lord warden of the Cinque Ports or under any act of parliament or charter, household servants of the crown, officers of the customs or excise, sheriffs' officers, high constables or parish clerks.

The justices in sessions have criminal jurisdiction, to be exercised partly according to the rules of common law and partly in a course prescribed by different acts of parliament; they have also jurisdiction in certain civil matters created by different statutes; they have an administrative power in certain county matters; and they have power to fine and imprison for contempt.

I. The criminal jurisdiction of justices in sessions, according to the course of common law, enabled them to try felonies and those misdemeanors which are not directed by any statute to be tried in a summary way. It has been said that they had no jurisdiction in cases of perjury and forgery; but this opinion seems to have arisen from the circumstance that at common law these crimes were only misdemeanors, and the authority of the justices extended only to such misdemeanors as were specially mentioned in their commission, or which came within the description of trespasses; and though most species of forgery have since been made felony, the opinion that courts of quarter-sessions had no jurisdiction in cases of forgery was commonly entertained.

The jurisdiction given by the commission of the peace, in respect of felonies, is expressed in very general terms, and in former times numerous executions for felony took place at the quarter-sessions. The practice during the present and the greater part of the last century was, however, not to try at the sessions persons charged with capital crimes, but to leave them for trial by the judges at the assizes. All questions of this description are, however, set at rest; for the criminal jurisdiction of justices in general and quarter-sessions is now defined by the 5 & 6 Vict. c. 38, which enacts "that after the passing of this Act neither the justices of the peace acting in and for any county, riding, division, or liberty, nor the recorder of any borough, shall at any session of the peace nor the adjournment thereof try any person or persons for any treason, murder, or capital felony, or for any felony which, when committed by a person not previously convicted of felony, is punishable by transportation beyond the seas for life," or for any of the offences mentioned under the 18 heads contained in the first section of the Act. The second section provides that any judge of the supreme courts at Westminster, acting under a commission of oyer and terminer and jail delivery for any county, may issue a writ or writs of certiorari or other process directed to the justices of the peace acting in and for such county, &c., or to the recorder of any court within the same county, commanding the said justices and recorder severally to certify and return into such court of oyer and terminer, &c., all indictments and presentments found or taken by such justices or recorder of offences which, after the passing of this Act, they will not have jurisdiction to try, and the several recognizances, examinations, and depositions relative to such indictments and presentments; and, if necessary, by writ or writs of Habeas Corpus, may cause any person in the custody of any jail or prison, charged with any such offence, to be removed into the custody of the common jail of the county, that such offences may be tried under the said commission.

Previous to the year 1836 it was in the discretion of the magistrate before whom the depositions were taken, whether he would allow them to be inspected; even the party accused had no right to demand a copy of the depositions, though in cases of treason or felony he was entitled to demand a list containing the names of the witnesses for the prosecution. But now all persons held to bail or committed to prison for any offence, may at any time after the completion of the examinations, and before the first day of the sessions (or assizes), require and have, from the person who has the custody thereof, copies of the examinations of the depositions on which they were held to bail or committed to prison, on payment of a reasonable sum for the same, not exceeding three-halfpence for each folio of ninety words. (See 11 & 12 Vict. c. 42, s. 27, substituted for the previous provisions of the 6 & 7 Wm. IV. c. 114.)

A prisoner or defendant charged with a felony or a misdemeanor, although entitled to defend himself by counsel, cannot have the assistance of counsel to examine the witnesses, and reserve to himself the right of addressing the jury. But if he conduct his defence himself, and any point of law arises which he professes himself unable to argue, the court will hear it argued by counsel on his behalf.

Where the quarter-sessions act as a court of criminal jurisdiction under the powers given by the commission, and according to the course of common law, a writ of error lies upon the judgment of the sessions to the court of Queen's Bench, and from that court to the Exchequer Chamber, and ultimately to the House of Lords. By the statute 11 & 12 Vict. c. 78, these courts, in common with the courts of Oyer and Terminer and Gaol Delivery, are empowered to reserve questions of law for the consideration of the court of Criminal Appeal; and by the statute 12 & 13 Vict. c. 45, the powers previously given to judges to order payments by way of reward for the apprehension of certain offenders was extended to these courts, the compensation to one person in no case to exceed 5*l.*

II. The quarter sessions have an original jurisdiction in all matters required to be done by two or more justices, except in cases in which a power is given of appealing to the sessions.

III. Statutes which give summary jurisdiction to one or more magistrates, in most cases allow their decision to be brought before the sessions by way of appeal. Notice of appeal is generally required, and the court is precluded from entertaining any objections not specified in the notice. Subject to this restriction, the case is heard as if the question were raised for the first time. Upon hearing of an appeal in which several counsel are employed, the course of practice usually is this:—the senior counsel for the respondent (the party resisting the appeal) states his case in accordance with the decision appealed against. The witnesses and documents in support of that case having been produced and examined, the senior counsel for the appellant addresses the court, and then his witnesses are examined. Both counsel for the appellant then address the court, and are followed by the counsel for the respondent; if no evidence is produced on the part of the appellant, the appellant's counsel sum up their case, and the respondent's follow. The practice in this respect, however, varies at different sessions. When the case is closed, the order, conviction, or other matter appealed against is confirmed or discharged, according to the view which the majority of the justices present at the moment of the decision take of the case, they being the judges in cases of appeal, both as to the law and the fact. Where, however, questions of difficulty in matter of law present themselves upon the hearing of an appeal, the party against whom the sessions decide frequently applies for leave to state a special case for the decision of the court of Queen's Bench: the majority of the justices may either grant or reject the application; and if no special case be stated, the judgment of the quarter-sessions upon an appeal, or upon any other matter in which they proceed in a course prescribed by statute, different from the course of the common law, cannot be reviewed by any other court. The stat. 12 & 13 Vict. c. 45, has amended the procedure in courts of quarter-sessions, by prescribing uniformity of time for giving notices of appeal; by conferring extensive powers of amendment; a large discretion as to costs; and by enabling them to refer matters to arbitration.

IV. The quarter-sessions have jurisdiction over the appropriation of the county stock, an annual fund raised principally by county rates. This part of the business of the court is usually disposed of before any other, and in practice the first day of the sessions is generally exclusively devoted to what is called "the county business."

V. In common with other courts of record, justices of the peace, whether assembled in sessions, or sitting as individual magistrates, may vindicate their authority by fining and imprisoning for contempt. No superior court can inquire into the existence or non-existence of the fact which has been so treated as a contempt, or into the reasonableness of the fine imposed or imprisonment awarded. The court of quarter-sessions has, however, no power of punishing contempts or other offences committed by one of their own body.

The justices being assembled in sessions elect a chairman. A panel, or list of persons returned to serve on the grand-jury, being called over, twenty-three, if so many appear, are sworn to inquire of the truth of the matters which will be brought before them, and not to disclose what is brought before them. If twenty-three do not appear, the court may proceed with a smaller number; but nothing can be done by the grand-jury without the concurrence of twelve of its members, and it is not usual to take less than thirteen, though twelve may be sworn, if, after waiting a reasonable time, more do not attend. Those persons in the panel who do not answer to their names are liable to be fined; and where it is thought desirable to ensure full attendance in future, the whole panel is called over for the purpose of discovering and punishing all the defaulters. The grand-jury being sworn, the royal proclamation against vice and immorality is read by the clerk of the peace. The chairman delivers his charge to the grand-jury, in which, as he is in possession of the depositions taken when the prisoners were committed, he calls their attention to such cases as appear to present any difficulty, and explains such points of law as are necessary for their guidance. The grand-jury then retire to their room to receive such bills of indictment as may be brought before them.

When the business of the sessions is such as to be likely to occupy a considerable time, it is usual to appoint a second chairman to preside in a separate court, under the authority of the 21 & 22 Vict. c. 73, substituted for previous provisions for the same purpose. The bills of indictment on parchment, with the names of the witnesses indorsed thereon, are taken to the grand-jury, who call in, swear, and examine the witnesses in succession, no other person being present. The examination being concluded, if a majority consisting of not less than twelve are of opinion that the charge is supported by the evidence, the bill of indictment is indorsed "a true bill," or the indorsement may state that the bill is true in such and such parts, and not true in others, or the grand jury may themselves strike out or alter any part of the bill, and return it in its corrected form as a true bill generally. If a majority of the grand-jury think that the party is not guilty, or if the number that think him guilty be less than twelve, they indorse "not a true bill;" though in the latter case the old form of indorsement, "ignoramus" (we do not know), seems to be more correct. It not unfrequently happens that grand-jurors return "a true bill" where the evidence which has been brought before them is such as merely to raise in their minds a strong suspicion of the guilt of the party accused, acting under an impression that it is not their duty to try the guilt of the party, and that the inquiry which has taken place in the grand-jury room is in the nature of a precognition little differing from the preliminary examination which takes place before a magistrate, who is bound to commit or to require bail if a probable cause of guilt be made out. By the common law of England, a man is not liable to punishment until the fact charged against him has been found to be true by the oath of twelve men (whether grand-jurors, leet-jurors, or jurors impanelled to try an issue in a civil cause involving a charge of crime), nor until such finding has been afterwards confirmed by the verdict of twelve others, forming the petty-jury, or by the confession of the party by pleading guilty in open court. The judgment of the court ought in strictness perhaps to be considered as founded upon the presentment of the grand-jury, and the proceedings which take place before the petty jury may be said to be less a trial of the guilt or innocence of the prisoner than a trial of the truth or falsehood of the indictment. The grand-jury are sworn to inquire, not whether the accused ought to be put upon his trial, but whether the matter in respect of which they are to make their presentment, contained in the bill of indictment, which directly and unequivocally asserts that a crime has been committed by the party, is or is not true. To return a bill as true upon less evidence than that which, if uncontradicted, would be satisfactory proof of guilt, seems to be at variance with an oath to present the whole truth and nothing but the truth. There appears to be no substantial distinction between a finding by the grand-jury that the party has committed the offence charged, and a verdict of "guilty" pronounced by a petty-jury. The finding of a true bill where the evidence is not sufficient to convict, is a wrong to the party accused. On the other hand, the justice of the country is not unfrequently defeated by forcing on a criminal charge to its final decision at a time when evidence sufficient to show the real character of the transaction has not been obtained; and by the inconsiderate haste of grand-juries in finding bills, the most atrocious crimes have not unfrequently obtained a total exemption from punishment. (8 Howell, 'State Trials,' 821, 836, 838; Burn's 'Justice,' "Indictment V.")

The bill, being indorsed, is brought into court by the grand-jury, and delivered to the clerk of the peace, who reads the indorsement with the name of the prisoner and the nature of the charge. By finding the bill to be true, either generally or in part, the grand-jury are become indictors, and the party charged the indictee; but these terms are nearly obsolete. The indictee is brought to the bar by the jailer, if in custody; or if out on bail, he comes of his own accord in discharge of his bail. He is then arraigned, and the trial proceeds in the same manner as at the assizes. [TRIAL.] If the prisoner be found not guilty, he is immediately set at liberty, unless there be some other matter before the court upon which he ought to be detained. If a verdict of guilty be returned, the sentence is pronounced by the chairman; such sentence, where the amount of punishment attached to the offence is not fixed, being first determined by the opinion of the majority of the justices present.

The sessions cannot be held without the presence of two justices, at least; nor can they be adjourned by one justice, though two or more may previously have been present. Every act done as an act of sessions before two justices have met, or after two have ceased to be present, is void.

The crown may grant a commission of the peace not only for an entire county, but also for a particular district within the county. In order, however, to exclude the interference of the county justices in the particular district, it is necessary either to introduce into the commission of the peace for the particular district a clause excluding the jurisdiction of the county magistrates, which is called a neintromittant clause, or to grant a new commission to the county magistrates excluding the particular district. If the former, which is the usual course, be taken, the county magistrates may still hold their sessions within the particular district, though they can exercise no jurisdiction in respect of matters arising within the district.

Petty and Special Sessions.—A meeting held by justices for the transaction of magisterial business arising within a particular district forming a subdivision of the county or district comprised in the commission of the peace, is called a petty session; and if the meeting be convened for some particular or special object, as the appointment of overseers of the poor, of waywardens, of examiners of weights and measures, &c., it is called a special session. A meeting of magistrates cannot legally act as a special session unless all the magistrates of the particular division are present, or have had reasonable notice to attend.

The statute 12 & 13 Vict. c. 18 makes further provision for the holding petty sessions in counties and boroughs, and declares that every sitting and acting of justices, or of a stipendiary magistrate for a city or borough, having a separate commission of the peace, shall be deemed a petty sessions. The fees of justices' clerks in petty sessions are moreover provided for by the 11 & 12 Vict. c. 43, and 14 & 15 Vict c. 55. [JUVENILE OFFENDERS; JUSTICES OF THE PEACE.]

Borough Sessions.—The Municipal Corporation Act (5 & 6 Wm. IV. c. 76) directs that the recorder of any city or borough to which a separate court of quarter-sessions is granted under the provisions of that Act, shall be the sole judge of such court [RECORDER], leaving the ordinary duties of magistrates out of sessions to be performed by the justices of the peace appointed by the crown for such city or borough. The recorder is required to hold a court of quarter-sessions once in every quarter of a year, or at such other and more frequent times as he may think fit, or as the crown may direct. Borough quarter-sessions are not, however, like county quarter-sessions, appointed to be held in particular weeks. In case of sickness or unavoidable absence, the recorder is authorised, with the consent of the town council, to appoint a barrister of five years' standing to act as deputy recorder at the next session, but no longer. In the absence of the recorder and of any deputy recorder, the court may be opened and adjourned, and the recognisances respited, by the mayor; but the mayor is not authorised to do any other judicial act. Where it appears to the recorder that the sessions are likely to last more than three days, he may appoint an "assistant-barrister" of five years' standing to hold a second court, for the trial of such felonies and misdemeanors as shall be referred to him, provided it has been certified to the recorder, by the mayor and two aldermen, that the council have resolved that such a course is expedient, and the name of the intended assistant-barrister has been approved of by a secretary of state.

Every burgess of a borough (or citizen of a city) having a court of quarter-sessions (unless exempt or disqualified otherwise than in respect of property), is liable to serve on grand and petty juries. Members of the town-council, and the justices of the peace, treasurer, and town-clerk of the borough, are exempt and disqualified from serving on juries within the borough; and they and all burgesses of boroughs having separate quarter-sessions are exempt from liability to serve on petty-juries at the county sessions.

Under the 105th section of the Municipal Corporation Act, the recorder has jurisdiction in respect of all crimes cognisable by courts of quarter-session in counties; but he is expressly restricted from making or levying any rate in the nature of a county rate, or granting any licence to keep an inn, &c., and from exercising any of the powers vested in the town-council. Other matters required by statute to be done at quarter-sessions, and not expressly transferred to the town-council, devolve upon the recorder, as the appointment of inspectors of weights and measures, &c. Persons imprisoned in a borough jail by county magistrates, under 6 & 7 Will. IV. c. 105, may be tried at the borough sessions for offences committed out of the borough.

All criminal jurisdiction which, before the passing of the Municipal Corporation Act, existed in any borough to which no court of quarter-sessions has since been granted, is taken away by the 107th section of that Act.

SESTE'RTIUS, a Roman coin, which originally consisted of 2½ ases, as the name implies, *sestertius* being a contraction of *semis tertius, the third a-half*, which is the Roman way of expressing *two and a-half*. The sestertius belonged both to the brass and silver coinage; and in both it was of the same value, namely, one-fourth of the denarius. This value agreed with its value in ases so long as the denarius consisted of 10 ases. But at an early period the as was reduced in value, and 16 ases made equal to the denarius [AS], and then the sestertius, its value with reference to the denarius remaining the same, became of course equal to 4 ases. On Mr. Hussey's computation the value of the denarius after the reduction was 8½*d.*, and therefore the sestertius was worth 2⅛*d.* After the time of Augustus the denarius was reduced to the eighth of an ounce, and was worth 7½*d.*, and therefore the sestertius was worth 1⅞*d.* The sestertius of the brass coinage was made of the same metal as the as.

The Romans generally reckoned sums of money in sestertii, although the coin used in making payments was commonly the denarius. Large sums they reckoned by *sestertia*, that is, sums of *a thousand sestertii*. It is very important to attend to the phrases used in such computations. The coin itself was called *sestertius*, or *sestertius nummus*, or simply *nummus*. The sum of a thousand sestertii was expressed by *mile sestertii*, or *M. sestertium*, or *M. nummi*, or *M. nummum*, or *nummorum*, or *M. sestertii nummi*, or *M. sestertium nummum*. The singular *sestertium* is never used for a thousand sestertii, but the plural *sestertia* is used for all multiples of a thousand sestertii, up to a thousand; sometimes the word *millia* (thousands) is used instead of *sestertia*; sometimes neither word is expressed; and sometimes *nummum* is added. Thus 600,000 sestertii, or 600 sestertia, might be expressed by any of the following phrases: *sescenta sestertia*, *sescenta millia*, *sescenta* alone, or *sescenta sestertia nummum*. Sums of 1000 *sestertia* and upwards were expressed by the numeral adverbs with the termination *ies*, which implies that the number to which it is affixed is to be multiplied by 100. Thus *decies, undecies, duodecies, vicies tricies, tricies quinquies*, stand respectively for 1000, 1100, 1200, 2000, 3000, 3500 sestertia. These forms are, however, sometimes varied. Thus Cicero ('in Verr.,' ii. 1, 39) uses *quaterdecies* for 1400, and *decies et octingenta millia* for 1800 sestertia. When two such adverbs come together, if the larger is first, they must be added together; but if the smaller is first, they must be multiplied. Thus we have in a passage of Suetonius ('Aug.,' 101), *millies et quingenties* for 150,000 sestertia, and immediately afterwards *quaterdecies millies* for 1,400,000 sestertia. (In the latter case, care must be taken not to reckon the termination *ies* twice over in multiplying; it is not 1400 × 100,000, but 14 × 1000 × 100.)

The symbol HS or IIS is often used both for *sestertii* and for *sestertia*. It stands for *libra libra semis* (two pounds and a-half). When applied to *sestertii* its meaning is clear enough, since the as was originally a pound (*libra*) of brass. When applied to *sestertia* it meant, according to Gronovius ('Pec. Vet.,' i. 4, 11), two pounds and a-half of silver, which he calculates to have been originally equal to 1000 sestertii, and therefore to have represented that value ever after. It is often difficult to determine whether the symbol HS stands for *sestertii* or *sestertia*. When the numeral is written in cipher, and has a line over it, it stands for the adverb in *ies*, and the HS means *sestertia*: thus, HS.$\overline{\text{CCCC}}$ is *quadringenties*, or forty thousand *sestertia*. Sometimes the numeral is found with the singular of *sestertium*, as *sestertii decies*, or *sestertio decies*. Gronovius explains these forms, and also the use of *sestertium* with the adverb in *ies* (which he considers to be, in this case, an accusative singular), by understanding with them the word *pondus*, a pound (of silver), according to which *sestertium* in these forms means two pounds and a-half of silver, or 1000 sestertii. Hence, if these forms are used with a numeral in cipher, they mean the number of *sestertia* represented by the adverb in *ies* of that numeral. Thus *sestertio X* is *decies* or 1000 *sestertia*.

According to the value given above for the *sestertius*, the *sestertium* was worth 8*l*. 17*s*. 1*d*.

The word *sestertius* is often used indefinitely for any very small sum. (Hussey, 'On the Ancient Weights and Money,' c. x., § 1, 3, 6.)

SET-OFF, in law, is the amount of the debt due to a defendant from a plaintiff, which the defendant is entitled to set off in answer either to the whole or part, as the case may be, of the plaintiff's demand. At common law, if the plaintiff was indebted to the defendant in an ascertained sum in respect of the same transaction concerning which the action was brought, the defendant was entitled to deduct at the trial so much from the plaintiff's demand. But if the debt due from the plaintiff accrued in respect of another transaction, the defendant had no such power; and he was either compelled to bring an action against the plaintiff for what was due to him, or, if he wished to avail himself of his cross-demand without bringing another action, to apply after the action had been commenced against him to a court of equity for the purpose of adjusting the claims of himself and the plaintiff. To obviate the expense and inconvenience of such a course, it was enacted by 2 Geo. II. c. 22, s. 13, that "where there are mutual debts between the plaintiff and defendant, one debt may be set against the other;" upon which statute, as explained by 8 Geo. II. c. 24, s. 4, is founded the whole law on the subject. A claim for damages not ascertained cannot be set off, even although they relate to the subject-matter of the action itself. For instance, in an action for goods delivered, the defendant cannot set off the loss which he has suffered by their non-delivery at the proper time, &c. There must also be an entire mutuality between the debt sued for and the set-off. Thus a debt due from the plaintiff together with other parties cannot be set off against a debt due to the plaintiff alone; nor can a debt due to the defendant personally be set off to a demand against him as executor, &c.: and the rule of law is the same for the converse of these cases. It is consistent with this rule that when an action is brought by or against a trustee, a set-off may be made of money due to or from the party for whom he is trustee.

A plea of set-off must describe the debt intended to be set off with the same certainty and particularity as would be necessary in a declaration, which indeed such a plea in several respects much resembles. If for instance a plea of set-off contains several parts stating distinct debts, these are analogous to distinct counts in a declaration, and one may be sustained although the others may not.

SETON. [Issue.]

SETTLEMENT. [Poor Laws.]

SETTLEMENT. A settlement, in the most general sense of the word, is a disposition of property of any kind made for certain purposes by the owner, who, in relation to such disposition, is called the settlor or grantor. A settlement in this case may be made either by deed or by will; but the term is most commonly applied to such settlements only as are made by a deed.

A consideration is not necessary for the validity of a deed at law. Though a deed may in many cases be void as against strangers for want of consideration, it is valid as between the parties. [Deed.] Settlements by deed, therefore, may be either made upon valuable or good consideration, or they may be purely voluntary.

The most important species of settlements—to which, indeed, in strict legal language, the term is exclusively applied—are marriage settlements; and these may be either such as are made previous to and in consideration of marriage, or subsequent to it.

Settlements of property are frequently made by will, with reference to an existing or future marriage. The forms and provisions contained in such instruments are, of course, often very similar to those in deeds made for like purposes. But dispositions of this kind are to be regarded in all respects as wills, and are governed by the same rules as other instruments of the like nature. [Will.]

Settlements in consideration of marriage include not only such as are actually made and executed before marriage, but also such as are executed after marriage in pursuance of articles in writing drawn up and signed before marriage.

1. First, as to the specific performance of articles and agreements to settle property:—

In Equity, no regard is paid to the form of marriage articles, and the construction of them depends entirely upon the intentions and objects of the parties.

When the intended husband and wife are both of full age at the time of the marriage, they are of course competent to enter into any agreement for the settlement of their respective estates, and all such agreements will be enforced in Equity; but if the parties are one or both of them minors at the time, the case is different.

When the husband is adult and the wife a minor, if the subject be real estate of the wife, the husband will be bound by the articles in respect of his marital interest in the lands; that is, for the estate which he takes during the joint lives of himself and his wife, and as tenant by the courtesy if he survive her and there have been issue of the marriage: but the wife will not be bound by them; and, if she die during infancy or after attaining majority, but without having confirmed the settlement in the mode prescribed by the law for disposition of real estate by married women, her heir will take the property unfettered by the articles. Again, if, in the case supposed, the property be personalty of the wife (which, in the absence of a settlement, would become the property of the husband), the articles will be valid as respects both husband and wife, being, in effect, the settlement of the husband. And this is true also as to chattels real and *choses in action* which become reducible into possession during the coverture; but, as to property already settled to the separate use of the wife, and *choses in action* which do not, in event, become reducible into possession during the coverture, the wife will not be bound by the articles.

If a male infant marry an adult female, he is bound by the articles entered into by her for the settlement of her estate, and must execute them when he comes of age, whatever be the nature of the property; but as to his own estate, he will not be bound by them.

When the husband and wife are both minors at the time of the marriage, the articles are absolutely null as respects them, unless confirmed after the attainment of majority. In such a case a confirmation of the articles by the wife must be express, and made in the same manner as any other alienation of property by a married woman; but confirmation on the part of the husband will often be implied from circumstances, such as the acceptance by him of any property under the articles.

It has sometimes been thought that the consent of parents or guardians, and the sanction of the Court of Chancery, might give effect to settlements of their property by infants, which would not have been otherwise binding; but it may now be considered as settled that there is no foundation for such a doctrine.

Marriage is regarded by the law as a valuable consideration, and will support a covenant entered into by a third party to settle property upon the husband and wife and their issue, whether the settlor be one under a natural obligation to make a provision, as in the case of a parent, or merely a stranger; and such a covenant will be enforced not only against the settlor himself, but against his heir, devisee, or personal representative.

Settlements made after marriage, when no valuable consideration (that is to say, no consideration in money or property) is given for them, are generally called, in contradistinction to those made upon marriage, voluntary settlements, and the persons who take under them are called volunteers; though, as such settlements may have good considerations to support them, the application of the term is not always strictly accurate. By a good consideration, as distinguished from a valuable one, is here meant that love and affection which is naturally supposed to subsist between near relations, such as parents and children, brothers and sisters, uncles and nephews or nieces.

Specific performance of voluntary covenants to settle property will be enforced in Equity only in favour of those persons for whom the covenantor is under a natural and moral obligation to provide; that is to say, in favour of his wife or children, but not in favour of any other class of volunteers. If, however, any valuable consideration has really been given, either by the person who, by himself or his representative, claims execution of the articles, or by a third person, in favour of the object of the limitation, specific performance will be decreed, and no objection can be made on account of want of relationship between the parties; and, for this purpose, it is sufficient if the fact of a consideration being given can be inferred from the circumstances. Though a person whose claim is not supported by a good or valuable consideration cannot himself compel the execution of articles in his favour, he may yet have the benefit of a suit instituted by another; for in decreeing specific performance, the court executes the entire articles, though they may embrace limitations to persons in whose favour it would not have originally interfered.

2. Next, as to the validity of marriage settlements against creditors and purchasers.

Marriage being a valuable consideration, the circumstance of the settlor being indebted, or even insolvent, at the time of the execution of the settlement, can have no effect on its validity, even though the persons who have the benefit of the settlement should have full notice of such insolvency. A conveyance or assignment of property in consideration of marriage stands on the same ground with a sale for money, which is not affected by the insolvency of the vendor. If, however, the settlor be a trader, and a fiat in bankruptcy be issued against him prior to the execution of the settlement upon which he is afterwards duly found a bankrupt, such settlement, like all other conveyances of the bankrupt under the same circumstances, will be void; and it would seem that a settlement must in all cases be void as respects the wife, if she had notice of a prior act of bankruptcy, and a petition be filed within twelve calendar months after such act of bankruptcy. (2 & 3 Vict. c. 11, s. 13.)

The marriage consideration does not extend or give the character of purchasers to all persons in whose favour limitations may have been introduced into the settlement. In relation to any other persons than the husband and wife and the issue, the settlement is, it seems, to be considered as voluntary, and subject therefore to the rules applicable to voluntary gifts and covenants.

Settlements made after marriage, it is obvious, can derive no support from the consideration of marriage, and their validity or invalidity must therefore depend upon other circumstances.

A postnuptial settlement by the husband, of any species of property made in consequence of a valuable consideration moving either from the wife herself, who gives up an interest that she possesses in property over which she has a disposing power, or from her relations or friends, is good against all persons whatsoever, if the consideration be not so inadequate as to raise the presumption of fraud. And even in case of inadequate consideration, the settlement, it seems, will be good to the amount of the consideration. It is sufficient if the consideration, though not paid, is properly secured. Contemporaneous settlements will in general be presumed to have been made in consideration of each other; and it seems that parole evidence of consideration is admissible, though none appear upon the instrument itself.

The statute 13 Eliz. c. 5, enacts that "all conveyances, &c., of lands and tenements, goods and chattels, made of malice, fraud, covin, collusion, or guile, for the intent or purpose of delaying or defrauding creditors and others of their just and lawful actions, suits, debts, &c. shall be deemed and taken (only as against those persons, their heirs, successors, executors, &c.) to be clearly and utterly void, frustrate, and of none effect; any pretence, colour, feigned consideration, expressing of use, or any other matter or thing to the contrary notwithstanding." But the act is expressed not to extend to any interest or estate made, conveyed, or assured, upon *good consideration and bonâ fide*, to any person or persons "not having at the time of any such conveyance or assurance to them made any manner of notice or knowledge of such covin, fraud, or collusion as is aforesaid." Upon this statute it has been determined, (1) That if the settlor be not indebted at the time, the settlement, even though entirely voluntary, is good against subsequent creditors; (2) That the mere existence of debts at the date of the settlement will not invalidate it if the settlor be solvent—that is, if he be possessed of property sufficient for the payment of his debts independent of the property so aliened; (3) That a settlement which might have been invalidated in the hands of the donee will be good against the creditors of the donor in the hands of a purchaser from the donee for valuable consideration without notice.

Voluntary obligations not affecting particular property, such as bonds, though the grantor should have been solvent at the time of making them, will not, it seems, entitle the grantee to come in *pari passu* with creditors for value, who will always be preferred; but the cancellation or release of a voluntary obligation, if untainted by fraud, may form a valuable consideration for the conveyance of property or for a substituted engagement.

By the 27 Eliz. c. 4, all conveyances, &c., of lands, tenements, or hereditaments are declared void when made with intent to defraud subsequent purchasers for money or other good consideration; "any pretence, colour, feigned consideration, or expressing of any use or uses, to the contrary notwithstanding." There is a saving of all conveyances made upon *good consideration and bonâ fide*. It also makes void, as against the same persons, all conveyances "with any clause, provision, article, or condition of revocation, determination, or alteration at (the grantor's) will or pleasure," whether such clause extend to the whole interest conveyed, or only partially affect it; but then follows a proviso "that no lawful mortgage made *bonâ fide*, and without fraud or covin, upon good consideration, shall be impeached or impaired by force of this act." This statute has been construed to extend to all voluntary conveyances, though not in fact made with intent to defraud, and though the purchaser had notice of the prior conveyance. The consequence of this is, though probably not intended by the framers of the Act, that it is impossible to make an irrevocable free gift of lands or tenements.

The statute 27 Eliz. c. 4, does not apply to personal estate. It has been determined on this act, by analogy to the determination on the last-mentioned act as to creditors, that a purchaser from a voluntary grantee will be preferred to a subsequent purchaser from the grantor. The *good* consideration mentioned in this and the preceding statute must be a valuable consideration (that is to say), either a property or marriage consideration. The consideration of blood has no application to either of these statutes, and therefore a conveyance made in consideration of "natural love and affection," as in the case of a postnuptial settlement upon a wife and children, is considered, for the purposes of these statutes, as voluntary. It has been decided, however, that a husband, having made a voluntary settlement on his wife and children, has no equity to compel specific performance of his contract with a subsequent purchaser; but he can sell the property which he has so settled, and the purchaser will have a good title, and can enforce performance of the contract for sale, if the husband should refuse to convey the property.

By stat. 21 Jac. I., c. 19, all voluntary settlements of traders were invalidated by their bankruptcy, though they might have been solvent at the time of making them; but the stat. 6 Geo. IV., c. 16, s. 73, and 12 & 13 Vict., c. 106, s. 126, placed the settlements of traders on the same footing with voluntary alienations in general.

Property cannot be settled so that the interest taken by any person under the settlement shall be unaffected by his bankruptcy; but it may be given to a man until he shall become bankrupt, provided there is a gift over of the property on that event. In the same manner the property coming from the wife may be settled on the husband so as to be devested on his bankruptcy. But when the property is the husband's own, it has been determined that, though the claims of the husband's creditors might have been defeated by a trust of the whole for the separate use of the wife, a limitation of the property to the husband until his bankruptcy, with a gift over in that event to the wife or any other person, is void. Upon the same principle, a bond or other obligation given by the husband upon his marriage, conditional for the payment of a sum of money to trustees for his wife and children in the event of his bankruptcy, is void as against his creditors who claim under the fiat or adjudication, if he has received no portion with his wife; but if he has received a portion with her, the obligation, being considered so far as a settlement of the wife's property, will be good against the creditors to the extent of it.

3. As to secret settlements and agreements in fraud of the marriage contract.

Secret settlements of her property made by the wife pending the treaty for marriage, without the privity of the husband, are void as against him, if made in derogation of his marital rights; and this, it seems, is equally true, whether the husband knew of the existence of the property before the marriage or not. The rule applies to every species of gratuitous incumbrance created by the wife upon her property under such circumstances.

The courts of equity, upon the general principles on which they act in cases of fraud, will set aside all secret covenants or agreements entered into contrary to the good faith of the marriage treaty, and not with the privity of all the parties to the settlement. Relief in such cases will not be refused even to a person who was a party to the fraudulent transaction of which he complains.

Upon the same principle, if a creditor or holder of any security or charge on the estate of one who is engaged in a treaty of marriage, misrepresent the amount of his debt or incumbrance to any of the parties to the contract, whether for the purpose of promoting the marriage, or for any other purpose, he will be bound by such misrepresentation. Money which has been lent to a woman for the purpose of being represented as her own, cannot, after the marriage, be claimed as a debt from the husband.

4. Settlements of real property usually consist of limitations of an estate or estates for life to one or more persons, that is (where the settlement is made on marriage), to one or both parents and the survivor of them, with remainders over to their children. This is what is called a limitation in strict settlement. By this method the estate is rendered inalienable till the eldest son of the marriage attains the age of twenty-one, when he can join with his father in barring his own estate tail and all the remainders over, whereby a new estate in fee simple is acquired, and the property may be settled again. [PRIMOGENITURE; REMAINDER.] This was formerly effected by means of a common recovery [RECOVERY], but it is now effected by a deed executed under the provisions of 3 & 4 Wm. IV., c. 74. By this act fines and recoveries are abolished, and the objects of these old modes of assurance are now obtained by a deed which must be enrolled in Chancery within six months after its execution. As, before this act, a tenant in tail expectant on a particular estate of freehold could only have barred his own issue by a fine [FINE], unless he could obtain the concurrence of the owner of the particular estate in suffering a recovery, so, under the new act, his power is equally limited, unless he can obtain the concurrence of the owner of the first existing estate under the settlement (whether it be for life or lives, or any greater estate, not being an estate for years) prior to the estate tail, who is called the protector of the settlement. The act contains several provisions for the purpose of ascertaining who shall be protector in the cases of joint ownership, coverture, and the existence of estates for years or in dower; and it provides for the cases where the protector is a lunatic, or convicted of treason or felony. The act also gives the settlor power to appoint by the deed a protector of the settlement, in lieu of the person who would otherwise have been the protector. The consent of the protector must be given either by the deed of assurance or by a separate deed, which must be enrolled in the same manner as the assurance itself. The same act repeals (except as to settlements made before the 28th of August, 1833) the statute of 11 Hen. VII.,

c. 20, whereby women who were seised of estates tail of the gift of their husbands (*ex provisione viri*) were prohibited from alienating them.

The estates limited in settlements of real property may be either legal or equitable. [Uses.]

When charges are intended to be created upon real estate, as for jointures or portions for children, it is usual to limit terms of years out of the estate to trustees for securing payment of the charges by perception of the rents and profits, or by sale or mortgage of the estate for the periods so limited. These terms are inserted at proper places in the settlement, according to their objects, among the other limitations; and such limitations as are subsequent to these terms of years in the order of arrangement, are also made subject to them in point of legal and equitable interest. It is usual to provide that the terms shall cease when their objects are accomplished or become unnecessary or incapable of taking effect.

Estates for lives and terms for years are incapable of being entailed; but they, as well as personal property of any kind, may be settled in trust as effectually, and so as to be inalienable for as long a time as estates of inheritance. The property in such settlements is usually assigned to trustees in trust for the husband, or for the husband and wife for his or their life or lives and the life of the survivor; and then in trust for the first and other sons severally, and the heirs of their bodies. This limitation vests the absolute interest in the eldest son, who will be entitled to dispose of the property upon his attaining the age of twenty-one; but in order to provide for the event of the eldest son dying under age and without issue, in which case his interest would otherwise vest in his father, if alive, as his heir or next of kin, it is usual to introduce a proviso that the property shall not vest absolutely in any son dying under the age of twenty-one years and without issue; and it has been determined, that, in construing settlements of both real and personal property, when the real estates are limited in strict settlement, and the personal property, according to a form frequently adopted, upon and for the same trusts, estates, and purposes as the freeholds, as far as the law will permit, a proviso of the kind above-mentioned is to be understood.

There is no restriction as to the number of life estates which may be limited in settlements to take effect in succession, provided the persons be all in existence at the date of the settlement; for, in point of fact, this amounts to no more than an estate for the life of the survivor.

Thus it appears that real or personal property may be settled so as to be inalienable for a life or any number of lives in being, and twenty-one years after. To this must be added a period of nine months, which is allowed for the birth of a posthumous child in cases where gestation exists. As the period of twenty-one years was no doubt adopted originally with reference to the term of minority, which must elapse before an estate tail could be barred, it was formerly thought that this period could not at all events be added to an executory trust; but it is now settled otherwise. All restraints on alienation beyond the above-mentioned limits are void, as tending to what is called in law a perpetuity; and all the subsequent limitations, if contingent, are also void. The same rules are applicable to executory devises, and springing and shifting uses [Wills; Uses]; but not to remainders limited to take effect after estates tail, which are not subject to any restriction; because, as such limitations may be defeated at any time by barring the estates tail, they can have no tendency to a perpetuity.

The forms of settlements may be varied according to the objects and intentions of the parties, and the construction of the articles upon which they are founded. The principle upon which a Court of Equity acts in executing marriage articles, is to look rather to the intentions of the parties as deducible from the circumstances, than to the literal meaning of the words employed by them. Thus, when the words used in articles concerning the settlement of real estate are such as would give the father an estate tail, and thereby enable him to defeat the settlement, the court will in general direct limitations in strict settlement to be executed, under which the father will take a life estate only. Upon the same principle, even though a deed of settlement has actually been executed after marriage, if it appear to be in any respects inconsistent with the letter or spirit of the ante-nuptial articles, the court will rectify it.

Questions frequently arise as to what powers, covenants, and provisos are to be introduced into marriage settlements made in pursuance of executory trusts, whether created by articles, wills, or other instruments. The determination of these depends entirely upon the rules of construction as applied to each particular case.

Of the powers usually introduced into settlements of real estate, the most important are—powers of jointuring and raising portions; powers of leasing and management; and powers of sale and exchange.

Where the wife, upon whose marriage the settlement is made, does not take a life interest in the estate in the event of surviving her husband, provision is usually made for her by way of jointure in bar of dower. [Jointure; Dower.] In addition to this, powers are frequently introduced to enable the husband, in case of his surviving his wife, and marrying again, and sometimes also the other tenants for life under the settlement, to make provision for their widows, by way of jointure, which the nature of their estate would not have otherwise entitled them to do. Powers of jointuring, and powers for charging the estate with portions for the benefit of the younger children of the then existing or a future marriage, will not, it seems, be inserted in settlements executed under the direction of a Court of Equity, without clear authority for them in the articles; for without such authority the court can have no data by which to regulate the quantum of interest to be taken by the donees.

Powers of leasing for the usual term of twenty-one years are essential to the management of an estate, and will be considered as authorised by the use of the most general expressions in the articles; or perhaps introduced as a matter of course; but a power to grant building leases will not, it seems, be implied without express authority.

Powers of sale and exchange are also considered as usual powers in a settlement, and will be authorised by the use of very slight expressions in the articles.

In settlements of personalty, where the property is assigned to trustees, they are empowered to invest and lay out the funds, and also to vary the securities from time to time. After the declaration of trusts for the husband and wife and children, such settlements usually contain powers of providing for the maintenance, advancement, and education of the children who are or may become entitled to shares in the funds under the preceding trusts.*

Settlements both of real and personal estate usually conclude with what are called trustee clauses, that is to say, clauses which enable the trustees to give effectual receipts; to provide for the appointment, when needful, of new trustees; for the indemnity of the trustees against involuntary losses; and for the payment of their expenses.

Marriage settlements sometimes contain covenants to settle particular lands; covenants to settle, or to purchase and settle lands of a certain value, or future real estate; covenants to settle present or future personalty; and covenants by parents, on the marriage of one of their children, to leave to that child an equal or some proportionate share with the rest.

The covenant to settle particular lands of course binds heirs, devisees, and all into whose possession the lands come, except a purchaser, for valuable consideration without notice; and, in case of the lands being so alienated, satisfaction may be claimed out of the general assets of the covenantor.

Questions frequently arise upon covenants to settle, or to purchase and settle lands of a particular value, as to what amounts to performance. On this point the following positions appear to be established:—1. Where the covenantor has no lands at the time, any purchase he may afterwards make will be presumed to have been made in pursuance of the covenant; 2. It seems, though there are conflicting authorities upon the point, that if the covenant be *to settle*, and the covenantor, having at the time lands adequate to the performance of the covenant, die without making any purchase, the lands which he had at the time will be bound to the extent of the covenant; 3. Where the covenant is to *purchase and settle*, it seems that no lands of which the covenantor is seised at the time will be affected, but all after-purchased lands will be affected to the extent of the covenant.

Covenants to settle future real estate of which the husband shall become seised during the marriage, or during his life, do not affect lands of which the covenantor is then seised, but extend to all after-acquired lands, even to such as come to the husband under the provisions of the deed of settlement.

Covenants to settle present or future personalty are considered as applying to capital only, not to income. If real estate should have been purchased with the personalty subject to such a covenant, the land is not bound *in specie* by the covenant, but is charged with the money invested in the purchase.

Covenants to leave one child an equal or proportionate share with the rest, attach only upon that portion of the settlor's property which may remain at the time of his death. The parent may therefore make an absolute gift of any part of his property in his lifetime to another child without committing any breach of his covenant; but a gift reserving any interest to himself is a breach of it. The benefit of such a covenant is confined to children living at the death of the parent.

5. Marriage is not an absolute gift to the husband of the wife's personal estate, but only entitles him to so much of it as he may have reduced into possession, assigned or released during his lifetime. Accordingly, questions frequently arise upon settlements as to the title of the husband, under them, to the whole of his wife's fortune. Upon this point the following propositions appear to be established:—1. The antenuptial settlement of property made by the husband upon the wife, in consideration of her fortune, entitles him only to her *then*, and not to the *future* personal property; 2. That if a part only of her fortune appears to have been stipulated for, the residue of what she then has, or what may afterwards accrue to her, will not belong to the husband; 3. That when it appears from the settlement, either expressly or by implication, that the agreement was for the whole of the

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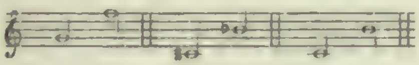
* Similar clauses are contained in settlements of real estate, where there are trusts for raising portions.

wife's present and future personal estate, the husband, or his personal representative (in case of his predeceasing his wife), will be entitled to claim the whole under the contract.

When the husband has not entitled himself by contract to the *choses in action* of the wife, there is no bar to his getting possession of such of them as are recoverable at law; but if he require the assistance of a Court of Equity for the recovery of them, and the wife does not consent to his obtaining the whole, that court will not lend its aid, except upon the terms of the husband's making a provision for the wife and her children, by way of settlement, out of the fund. Most frequently one half of the fund is directed to be settled, but the proportion given in each case depends upon the circumstances, though it never amounts to the whole. The rules of the Court of Equity in directing settlements out of the wife's equitable *choses in action* are the same, whether the application to it is made by the husband himself or by his creditors. Settlements out of the wife's equitable *choses in action*, when made by the husband, are no less valid against his creditors than when made under the direction of the court; and even a settlement by him of the entire fund, which the court would not have directed, has in some cases been held valid against his creditors; though the decisions in those cases seem hardly consistent with the law as laid down under the 13 Eliz., c. 5. It should be added, that now by the stat. 20 & 21 Vict., c. 57, a married woman is empowered to release, with the concurrence of her husband, her equity to a settlement in property to which she may be entitled under any deed dated subsequently to December 31, 1857; also to dispose of reversionary interests under such settlements. But these enactments do not interfere with the principles above stated. (SEPARATE USE; Bright on *Husband and Wife.*)

SEVENTH, in music, a dissonant interval, of which there are three kinds,—the minor or ordinary seventh, from G to F; the diminished seventh, from C sharp to B flat; and the major or sharp seventh, from C to B. Ex.:



For the *chord* of the seventh, its inversions and treatment, see CHORD.

SEWERS. In its original acceptation, the word Sewers meant simply the banks, or sea-weirs, erected for the purpose of protecting the low lands by the sides of tidal rivers, from the effects of inundations or high tides; but, by extension, the word has been applied firstly to all artificial channels which discharge the surface drainage of lands on a comparatively speaking high level into a natural water course, by outlets on its shores (whence the old synonyme for sewer, *shore*); and of late years the word has been so exclusively applied to the subterranean artificial water-courses of towns destined to relieve them of both the surface drainage, and the liquid refuse of the houses, as to have caused the original meaning to be entirely lost sight of. It is however so convenient to adopt a special name for town drains, and the modern sense of the word *sewer* is so universally received, that in the succeeding remarks, it will be exclusively so employed; or, in other words, whenever *sewer* is used, it will be in the sense "of an artificial channel for the removal of surface, subsoil, or house waters."

The earliest recorded instances of the use of sewers is in the palace of Nimroud, and in the more celebrated Cloacæ of ancient Rome; but none of the drains of this description executed by the ancients were used for the purposes to which they are applied in the more highly civilised countries of modern times. The cloaca maxima itself was formed for the purpose of draining the Campus Martius, and the low swampy lands between the Seven Hills, in precisely the same manner that the Égout de ceinture of Paris drains the valley of the Marais, Menilmontant, and Montmartre of that city; and though no doubt the house waters of the capital of the ancient world found their way eventually into this huge drain, it is notorious that the Romans never were acquainted with the modes of house sewerage we have lately applied. One of the first legislative enactments of modern times on the subject of sewers was an act, 9 Henry III. (about 1225), which was followed by others, 6 Henry VI.; 8 Henry VI.; 4 Henry VII.; 6 Henry VIII.; and the whole of the legislation then prevailing was carefully reviewed and condensed, by Sir Thomas More, in the celebrated 'Bill of Sewers,' which became law in 25 Henry VIII. (or in 1531). In France attention had also been directed to the subject of the drainage of the capital towards the close of the mediæval period, for in 1412 the grand Égout de ceinture (then called the ruisseau de Menilmontant) was built; and in 1550, Philibert de l'Orme was instructed to examine and improve the drainage of Paris. The governments of both England and France continued from these periods actively to interfere with the regulation of these important works; but, in accordance with the respective idiosyncracies of the two nations, the courses adopted were essentially different. In the one case, the power was handed over to local commissions; in the other, it was retained exclusively in the hands of the central government; the consequence being, as might have been expected, that in the former case there was displayed much irregular energy and enterprise, in the latter there was displayed a singular amount of scientific indifference. Without dwelling on this political part of the questions connected with the execution of public works, it is to be observed that ultimately, about the year 1834, there were no less than eight separate commissions entrusted with the superintendence of the sewerage and drainage of London; and so great were the evils then found to result from the variety of practice tolerated by the different boards, and from their discordant jurisdictions, that at last, after many efforts, the local boards were suppressed, and in 1848 the "Metropolitan Commissioners of Sewers" were appointed, with extensive powers over the whole of the Metropolis. A few years later the management of the sewerage of the Metropolis was transferred to the Metropolitan Board of Works instituted by the Act of 18 & 19 Vict. c. 120 (passed 14th August, 1855). The sewerage of the provincial towns of England is now either left under the control of the local paving and draining commissions, or of the municipal corporations acting under special acts of parliament; or it is carried on under a species of government superintendence, under the powers of the Public Health Act, 11 & 12 Vict. c. 63 (passed 31st August, 1848), which has been limited by the passing of some subsequent acts, such as the Act of 1854, and the local government act of 1858. In France the administration of the laws regulating the Égouts remains under the control of the Department of Public Works, and the Municipalities have practically no power over the matter.

Until a very recent period, the subterranean channels of London were exclusively used as drains for the removal of surface, subsoil, and ordinary house waters; and the discharge "of any filth or soil into any common, or public drain, or sewer" was even, by the Act 57 Geo. III. c. 29, made punishable by a fine. Subsequently to that period, however, the universal application of the water closet system has forced the various authorities connected with the sewers to tolerate in the first place, and finally to regulate, the discharge of the excreta of the inhabitants of towns into the sewers. To such an extent does this now take place, that the modern use of those subterranean channels has become of infinitely more importance than the original one, and the word "sewerage," or sewage, has been invented for the purpose of expressing the waters employed for the removal of house refuse of the description alluded to. Unfortunately the legislature has hitherto neglected to direct its attention to the evil produced by the new system, by thus discharging, eventually, the whole of the town refuse into the natural water courses of the country; and though no doubt many of the details of the sewerage of our towns have of late years been much improved, much still remains to be done, not only for the purpose of securing the purity of the rivers and streams, but also for the useful application of the fertilising matters now so sadly wasted.

One advantage appears to have resulted from the discussions which have taken place with respect to the legislative, administrative, and executive measures required to meet the case of the metropolitan sewerage, namely, that at last many of the exclusive theories propounded by the admirers of hydraulic engineering, as it is *not* practised by *eminent* hydraulic engineers, have been set aside; whilst all that was good in the technical modes of operation introduced by this new school has been retained. At the present day the principles most generally admitted as being applicable in designing a complete system of town sewerage may be stated to have been elicited from the discussions thus referred to, and to be as follows, in all normal cases at least. It must, however, be understood that they are based upon the supposition that the town in question is in a thriving condition, and likely to double its population in fifty years; that its relief is such as to afford tolerably favourable rates of inclination in the main sewers; and that there is a good water supply to every house. The rain-flow to be provided for from the paved and non-absorbent parts of the town, may be taken at about ¼ inch in 24 hours if proper storm overflows can be obtained; that from open gardens, cultivated lands, &c., may vary according to the nature of the soil, from ¼ inch to ½ an inch per day Under-ground springs must be allowed for, if they should exist in any serious quantities, as is frequently the case in towns situated upon the outcrop of a geological stratum, or upon a bed of permeable materials surrounded by high lands able to drain into them. In some cases, the latter condition may even require that a system of intercepting drains should be formed, so as to isolate the area of the town from the hydrographical basin surrounding it, and to confine the sewerage operations to that especial purpose.

These conditions premised, before settling the dimensions of the main sewers, it is necessary to divide the town into sections corresponding with the great physical divisions of the district, and to ascertain for each of the latter: 1, the area to be relieved; 2, its actual and prospective population; 3, the amount of the house sewerage it would be likely to furnish (this is usually at the rate of 5 or 7 cubic feet per individual, and it is found that at least one-fourth of that quantity is discharged between the hours of eleven and one, so that it is advisable to calculate the house sewerage at nearly 1 cubic foot per head per hour); 4, the rain-flow; 5, the length of the sewer, and the inclination it would be possible to give to its invert, because the two last named conditions will affect the dimensions of the cross section. As to the house sewers, it is useless to attempt to proportion their area and fall to the quantity of waters they may discharge, because it has been found practically that the public in general is so careless in its manner of treating those sewers, that anything less than a 6-inch pipe drain will infallibly be choked within a very short time. So long as the pipe drains thus referred to run under the houses themselves, they should be jointed in cement, and under all circumstances they should be without junctions at right angles. The highest point of the sewer should be laid, if possible, at 2 feet at least below the lowest part of the basement story it is intended to drain; and it would be desirable to make the longitudinal fall about 1 in 65; the house sewers should be made perfectly impermeable, and if any land springs should happen to occur in the surface occupied by the house they should be carried off by a special system of drains. In order to guard against the flooding of basements, by any accidental accumulation of waters in the main sewers, it is desirable that the connection between them and the house sewers should be effected at a small height above the upper line of the invert of the main sewers; but care must be taken to prevent the formation of any current, or of any obstruction, able to produce a deposit near the point of junction. Especial precautions must be taken to trap all communications with the sewers which might otherwise admit the escape of gases into the house; all rain-water pipes should discharge their waters into the upper ends of the sewers, if possible; and under some circumstances the rain-water pipes may be made to serve as ventilators to the sewers, when their joints are remarkably well made, and the heads are fixed above every opening of the house. One of the favourite theories of the late General Board of Health was to the effect, that what was then called "combined back drainage" (or the connection of a number of small house sewers at the back of the blocks of houses, with other small sewers of an area barely sufficient to discharge the united amounts of sewerage), was the cheapest and best method of removing those waters; but so many serious inconveniences have been found practically to attach to this system, that at the present day it is generally abandoned, and the house sewers are almost always carried directly from each house into the main sewers in front of them.

In the execution of the street sewers (the sub-mains, in fact, of the sewerage of a town), care must be taken that their dimensions should be sufficient to carry off any occasional storms; that means should be provided for the easy examination and repair of the works; and that no obstacle should be presented of a nature to provoke a deposit of the matters brought from the houses, or from the streets themselves. The junctions of the house sewers should be made with curves of considerable radius; the surface waters from roads and streets must be received in trapped cesspools, so constructed as to intercept all solid matters, and to collect the fine mud washed from those surfaces in an available form, because it is often of commercial value as a manure; the ventilation of the sewers must be effected in such wise as not to inconvenience the dwellers in the neighbouring houses, and for this purpose it is preferable to insert ventilating holes in the middle of the roadway, whilst the side gullies should be carefully trapped; and side entrances with flushing gates, or other machinery, must be provided according to the local peculiarities of the sewer. The principles which regulate the size and the materials of street sewers are, firstly, that the smallest possible frictional area should be presented to the flowing current, and that the water should flow without being under pressure; secondly that the actual channel for the sewerage should be impermeable, but there are some cases in which it is actually desirable that the sewer should give free passage to the land waters at levels above the line of their own maximum flow. Now of all forms of cross section, a semicircle is the one which presents the smallest frictional area; and it may be laid down as a law that, in most cases, the impermeable cylindrical stone-ware pipes are the best materials which can be employed for street sewers, provided their dimensions are not required to exceed 2 feet in diameter; beyond that diameter, however, it is difficult to obtain pipes of a sound character, and they become more expensive than brick culverts of the same area. There is another consideration which also requires to be taken into account, in cases wherein the diameter of the water-course exceeds 2 feet, namely, that it frequently becomes necessary to cleanse them by hand labour. A man can crawl through an oval channel 2 feet wide by 2 feet 6 inches high, so that those dimensions may be taken as the minima ones for street sewers in districts where it would be difficult or objectionable to open the roadways; and sewers of such forms are far more conveniently made in brickwork, than in stone-ware pipes. Brickwork sewers, moreover, present the advantage of allowing lateral junctions to be made more easily than would be the case with stone-ware pipes. The sizes of street sewers usually adopted, when the requisite dimensions exceed an area equal to that of a semicircle of 2 feet in diameter, are (the transverse section being now made of an egg shape) either 3 feet 3 inches deep, by 2 feet wide at the minor axis; 4 feet, by 2 feet 6 inches; 4 feet 9 inches, by 3 feet; 5 feet 6 inches, by 3 feet 3 inches. The dimensions of such sewers as the Fleet sewer of course cannot be brought under any normal law, for it drains an area of not less than 4400 acres, half of which is covered by houses, and has been known to run with a stream of not less than 106 feet superficial area. The best velocity of the flow in street sewers is about 1¾ to 2 miles per hour, and the rate of inclination of the bed should as far as possible be made equal to 1 in 240; below that inclination it becomes necessary to flush the sewers from time to time, in order to keep them clear. The junctions of street sewers with one another should be made with their centre lines of invert on the same level; the junctions of these sewers with the main sewers should, however, take place so that the centre line of the latter should be a few inches below those of the branch sewers.

As frequent allusion has been made to the land waters it is often requisite to remove by the means of sewers, it may be as well to observe that unless drains should be laid down for the express purpose of relieving the subsoil of those waters, or unless there should exist some natural outlet for them, the main and sub-main sewers should be made either with inlet holes or of partially permeable materials above the level of the ordinary storm flow of the sewerage. Sufficient attention is rarely paid to this condition of the soil of sandy or of gravelly districts, and it frequently happens that, in towns wherein a good system of house sewerage exists, the basements are flooded by the land waters, because the latter cannot find their way into the impermeable main sewers. When the feeding grounds, so to speak, of the springs are extensive, the best course certainly is to execute an intercepting drain, so as to separate the inhabited area of the formation from the open soil of the country. An instance of the evil thus alluded to is to be found at Southampton, and another in the quartier Montmartre in Paris; and in both of them the inundations of the basements, after long-continued wet weather, are often productive of serious evils. Perhaps it may be desirable to cite, as an additional reason for preferring the construction of a special system of intercepting or land drainage for the removal of the springs, that when they are removed by the agency of the sewers there is a possibility that the foul waters flowing in the latter may permeate the land around them at certain seasons. As a general principle it would unquestionably be preferable to confine the drains and sewers to their respective functions; but in this, as in all cases connected with practical engineering, local considerations may often render it prudent to modify absolute theoretical laws. It is worthy, however, of especial remark that the formations which are thus exposed to become charged with underground waters, are characterised by the frequency and the violence of the typhoidal fevers which prevail amongst the town populations located upon them. As a sanitary measure, the drainage of such lands is nearly as important as the sewerage of the houses and streets can be.

The main drains of a system of town sewerage are of course to be calculated as to their dimensions upon the same principles as the sub-mains; that is to say, they must be proportionate to the area, the rain flow, and the amount of sewerage, to be dealt with. The waters coming into the mains are usually animated by a velocity rather in excess of the one which would be requisite to maintain the rate of flow necessary to preserve a clear channel for the larger volume of water in the united stream; and from the ordinary laws of hydrodynamics it follows that the inclinations of the main sewers may without inconvenience be made less than those of the sub-main sewers. It is, however, desirable to keep the inclinations of the former at least at the rate of 1 in 500, though occasionally when great facilities for examination and repair may exist, that rate may be reduced, without serious inconvenience, to 1 in 1000. Great precautions are required in the construction of main sewers to secure an efficient ventilation; and, wherever it is possible so to do, storm overflows should be provided. This latter precaution of course can only be adopted when the discharge of the contents of the main sewer takes place by gravitation; if the discharge should take place by artificial means, it will be found necessary to construct the main sewers of dimensions able to contain any occasional accumulation of storm waters.

Hitherto the final discharge of sewerage waters has been effected by merely pouring them into any natural water-course, to the great injury of the latter, and to the great disgrace of the authorities who pretend to watch over the sanitary interests of the country. It is true that some very earnest attempts have been made to apply the sewerage to the purposes of agriculture, both in a solid and in a liquid form; and it is equally true that hitherto those attempts have not been successful in a commercial point of view. Nevertheless, the importance of the subject, as proved by the gradual contamination of the Thames, for instance, is so great that no mere money considerations ought to be allowed to stand in the way of the compulsory application of some efficient measure for the deodorisation and purification of town sewerage before its discharge into any superficial water-course. The experiment tried at Leicester, of precipitating the solid matters from the sewerage, has proved at least that the operation can be effected at a moderate rate per head of the inhabitants of a town; the results of the Rugby and Watford experiments, of pouring the sewerage in a liquid form over agricultural lands, although far from successful up to the present, have not been of a nature to discourage further attempts to dispose of that fluid by irrigation, especially in agricultural districts. In the case of Rugby the sewerage is distributed, over a mixed area of arable and of pasture lands, by a system of cast-iron pipes and moveable hose, which has necessarily increased the first cost of the distributing apparatus and of the subsequent working; if, instead of these costly follies, the sewerage had simply been pumped up to a high level, and a surface irrigation by gravitation had been thence effected, the results would in all probability have been very different from those which were actually obtained.

Some idea of the importance of the sewerage works lately executed in England may be formed from the facts that there is now hardly a town wherein they do not exist in a more or less perfect form; and that the average cost has latterly been at the rate of at least 1*l.*

per head of the population of the towns. The average sewers-rates of well-drained towns seem also to be about 2½ per cent on the rental of the houses.

It may be added that in the London sewerage there appears to be present about 1 ton of solid matters to every 266 tons of water; but in very unfavourable cases the proportions of solid to liquid may increase to 1 in 96, or even to 1 in 36; the proportion of 1 in 66 is considered to be the largest which is consistent with the safe working of pipe sewers, in which the fluid can move with a velocity of 3 feet per second.

(Consult 'Reports of Health of Towns Commission,' and the various Blue Books on the London Sewers; 'Transactions of Civil Engineers;' 'Annales des Ponts et Chaussées,' &c.)

SEXAGESIMA, the second Sunday before Lent, or the next to Shrove Tuesday; so named, as being, not exactly, but about the sixtieth day before Easter. Brady, in his 'Clavis Calendaria,' vol. i., p. 175, says, "The name of the first Sunday in Lent having been distinguished by the appellation of Quadragesima, and the three weeks preceding having been appropriated to the gradual introduction of the Lent fast, it was consistent with propriety to call the three Sundays of these weeks by names significant of their situation; and reckoning by Decades, the Sunday preceding Quadragesima received its present title of *Quinquagesima*, the second *Sexagesima*, and the third *Septuagesima*.

SEXAGESIMAL, a name given to the system of reckoning in which each unit is the sixtieth part of the preceding, to which, in our day, we are only accustomed by the method of measuring angles and time. The Greeks, and Ptolemy in particular, brought this method into use in astronomical matters, and their successors seem to have attempted to make it a general mode of reckoning. There exist treatises of arithmetic fashioned on this system; one, for instance by BARLAAM. [BIOG. DIV.]

In the sexagesimal arithmetic, $17\ 26'\ 48''\ 53'''\ 9^{\mathrm{iv}}$ stands for 17 units + 26-sixtieths of a unit, or 26 minutes or *scrupula prima* [SCRUPLE] + 48-sixtieths of a minute, or 48 seconds or *scrupula secunda* + 53-sixtieths of a second, or 53 thirds or *scrupula tertia* + 9-sixtieths of a third, or 9 fourths or *scrupula quarta*.

Addition and subtraction are easy enough in this system; multiplication, division, and the extraction of roots are more complicated. If we had, for example, to multiply $7\ 26'\ 43''\ 51'''$ by $11\ 47'\ 18''\ 56'''$, each term of one factor must be multiplied by every term of the other, and the denomination of each product must be as high as those of both factors put together. Thus when we come to $43'' \times 56'''$, the result must be in fifths ($2 + 3 = 5$); and 43×56 being 2408, we have 2408^{v}, or $40^{\mathrm{iv}}\ 8^{\mathrm{v}}$. This process was aided by a large sexagesimal multiplication table, which may be seen in Delambre, 'Astronomie Ancienne,' vol. ii. There is also a large sexcentenary table, constructed by John Bernoulli (III.), and published (or republished) by the British Board of Longitude. There is little need to give any further account of sexagesimal processes.

SEXTANS (the sextant), a constellation which Hevelius had the singular bad taste to place on the back of the Hydra and at the feet of the Lion. It comes directly between the bright stars α Leonis (Regulus), and α (or Cor) Hydræ. There are no stars of conspicuous magnitude in this constellation.

SEXTANT. The history of the sextant was involved in some doubt until the late Professor Rigaud undertook to investigate the subject. The result will be found in the 'Nautical Magazine,' vol. i., p. 351, and No. xxi. The following account is a brief outline of his inquiry.

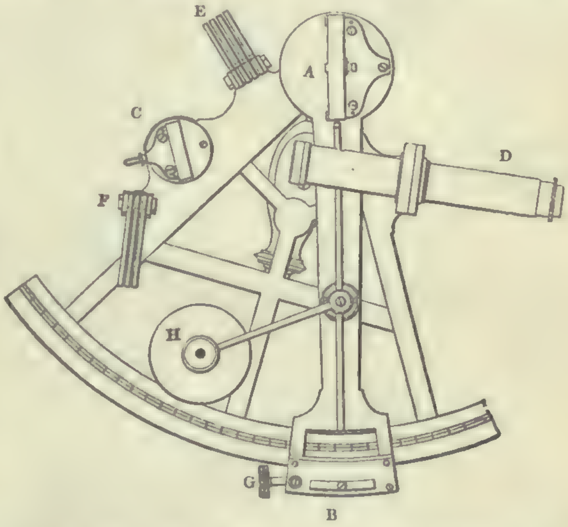
The early modern navigators used the *cross-staff*; this was afterwards exchanged for Davis's *back-staff*, called by the French *quartier anglais*. Hooke proposed an instrument for the purpose of taking altitudes at sea, which is very ingenious; the sun was seen reflected from a plane glass, while the horizon was viewed directly.* Hooke does not seem to have esteemed his invention so highly as it deserved; for in a subsequent lecture on astronomy and navigation, in 1694, he makes no mention of this, but describes a quadrant of a different construction. In 1699, Newton exhibited an instrument to the Royal Society, which is described as "the old instrument mended of some faults;" and at some later time he communicated to Dr. Halley a scheme for an instrument which was probably never executed, but of which a drawing and description were found among Dr. Halley's papers after his death in 1742. ('Phil. Trans.,' vol. xlii., p. 155.)

The date of the invention of Hadley's quadrant was proved, on examination by the Royal Society, to have been not later than the summer of 1730. A notice of it was given at a meeting of the society, May 13, 1731; and the instrument exhibited May 27. The memoir is published, vol. xxxvii., p. 147.

At the meeting of the society, May 20, Dr. Halley expressed an opinion that the principle of Hadley's new instrument had been discovered and proposed by Newton, and a search was made into the minutes of the society to ascertain the fact. The only notice which could be found was that already mentioned,—namely, in 1699,—and this was clearly an improvement of an old instrument, and not the proposal of one new in principle. Halley, at a meeting on the 16th of the following December, expressed himself satisfied that Hadley's instrument was much different from that formerly invented by Sir Isaac Newton. It seems not unlikely that Halley's recollections were of the instrument which Newton had proposed to him, and the description of which was found among his papers, but that he had forgotten the manner of the communication, and confounded the latter instrument with that which Newton had exhibited to the Royal Society. This is, we think, a very probable failure in the memory of a man of seventy-six, and what many younger persons experience daily. That Halley did not immediately see the advantages of Newton's latter proposal may appear a little strange; but Halley's forte clearly did not lie in mechanical construction or astronomical observation.

A little after Hadley's invention,—namely, about October or November, 1730,—Thomas Godfrey of Philadelphia, a glazier by trade, proposed and had executed an instrument which he called a bow, very much resembling Hadley's earlier construction. This was described in a letter to Dr. Halley from James Logan, Esq., dated 25th May, 1732. Mr. Logan had put off writing more than twelve months after the instrument was placed in his hands, and this neglect threw some doubt on the originality of the invention, which could only be satisfactorily established by additional evidence. After examination, the Royal Society came to the conclusion that Godfrey's discovery was also original. We think it is clearly proved that the priority is due to Hadley, and that there is no pretence for doubting Godfrey's originality. Some hasty writers, adopting mere hearsay for their guide, have attempted to give the subject a national and *patriotic* colour, which, unphilosophical at all times, is a simple absurdity when the contending parties are, as in this instance, of the same race. We have thus tried to give a hasty summary of Professor Rigaud's statements and conclusions, which we entirely adopt. The perusal of the original memoirs will gratify the lover of exact and discriminating research. Hadley's second construction, which is incomparably superior to his first and to Godfrey's bow, scarcely differs from the present sextant.

The sextant is figured and described in almost every book of navigation, and is so commonly to be met with that we shall be very brief. A is a plane glass, called the *index* glass, silvered behind, and perpendicular to the face of the instrument. It is fixed on a centre perpendicular to the instrument, and moves with the *index bar* A B, the end of which, B, slides over the graduated arc. C is a plane glass, the lower half of which, next the instrument, is silvered, and the upper half left clear. It is called the *horizon*-glass, and should be parallel to the index-glass when the index points to 0° at the beginning of the arc. D is a telescope for viewing the objects observed. This should be of good quality and with an inverting eye-piece. In the common quadrants there is merely a plate with a small hole for directing the sight. Suppose a ray of light to proceed from the eye, it will proceed in the direction of the telescope; and if it falls on the upper or unsilvered part of the horizon-glass, it will pass forward in a continued straight line until it falls upon some exterior object. But if the ray falls upon the silvered part of the horizon-glass it will be reflected to the index-glass (the horizon-glass is so placed as to make equal angles with lines from the eye and index-glass), and again reflected from the index-glass, outwards (that is, from the observer), until it meets some external object. Now instead of supposing the rays to pass from the eye, suppose them to come from external objects to the eye; then there will be two images presented at the same time, one formed by the rays which pass through the unsilvered part of the horizon-glass, and another formed by the rays which have been previously reflected by the two glasses; and it is easily shown from the elementary principles of optics, that when two objects are thus appa-



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* This is described in Hooke's 'Posthumous Works,' p. 503, and was probably presented to the Royal Society in 1666. In practice, besides some other objections, it would have been troublesome to ascertain the *index error* in this construction.

rently seen in coincidence, the angle which they subtend at the point of meeting is exactly double the angle which is contained between the planes of the index and horizon glasses, if these be supposed to be prolonged until they meet. Hence, if the index be at zero when the glasses are parallel, and if the arc be divided into half-degrees which are numbered and subdivided as whole degrees, the arc actually read off, after any such observation as is here described, will measure twice the inclination between the glasses (for this inclination is evidently the same as the angle between the parallel position of the index-glass and its new position), and, in consequence of the optical principle above mentioned, this will be the true measure of the angle between the objects when they are so distant that the place of the eye and the intersection of the rays may be considered to be the same. The sextant, therefore, furnishes the means of measuring the angle between any two well-defined objects, in whatever direction they may be placed (so that the angle does not exceed 140°), and without requiring more steadiness than is necessary for seeing the objects distinctly. E and F are sets of dark glasses of varying intensity, which may be turned before either the index- or horizon-glass when required; G, a tangent-screw for giving slow motion to the index-bar; H, the reading microscope and reflector. The handle below is visible in the drawing, and there is a screw behind the collar of the telescope for giving an up-and-down motion to the telescope, which alters its distance from the plane of the instrument without affecting its parallelism thereto.

The adjustments of the sextant may be divided into those which more properly concern the artist and those which are to be attended to by the observer. It should be distinctly understood that no other instrument requires so much care and skill in its construction and use as the sextant. There are scarcely half a dozen makers in England, and probably not double that number in all Europe, who are fit to turn out a sextant; and though skilful sextant observers are somewhat more plentiful, they are still exceedingly rare. The fabric of the sextant should be strong and light. A blow which would not seriously damage a theodolet or circle, where three or more readings correct pretty nearly the errors which arise from such injury, would entirely ruin a sextant; but while giving strength, the maker must be on his guard to avoid weight. Troughton and Simms's double-frame sextants of 8 inches radius are a very good model, those of 10 inches are too large; single-frame sextants may be had of 7, 6, or 5 inches radius. All these sizes have or may have the same telescope, glasses, and shades. Those which we have hitherto seen seem to admit of some improvement in their scheme. Mr. Dollond casts his sextants in one piece of hard metal, which is an improvement, and very beautiful instruments they are. The limb of the instrument should be perfectly plane, and the axis on which the index-glass turns exactly perpendicular to it. If a purchaser is sufficiently confident in his own judgment to rely on that, rather than on the reputation of the maker, he should release the clamp, observe whether the index-bar moves easily and without shake along the whole arc, and also whether the vernier seems to press equally in every position. The telescope should be of the best quality, with a large aperture and of as short a focal length as these conditions permit. It should show the edge of the sun and moon quite sharp and distinct with the highest powers employed. The index-glass is generally the most faulty member of a common sextant; the faces are not parallel, and consequently when rays fall very obliquely upon it (in which case those reflected from the front surface are nearly as copious as those from the silvered back), there are two faint and separated images seen instead of one bright one. The artist tries his index-glasses by the following test: The sun is viewed with a high power after *very* oblique reflection from the index-glass, and those glasses only are retained in which the image is single and sharp. The rejected glasses find their way to the second-rate makers. The horizon-glass, which is smaller and on which the rays fall at a larger angle, does not, if imperfect, affect the images so much, but it too should be examined. The shades or dark glasses, which are either interposed between the glasses or placed before the horizon-glass, are next to be examined. The two images of the sun are brought into proper contact, after applying the highest power to the telescope and putting the proper dark glass on the eye end. One of the lightest shades is then interposed between the index and horizon glasses, and if the contact is slightly disturbed, this shows the form of the shade to be prismatic. The shade is turned in its cell until the effect is perpendicular to the plane of the sextant. The corresponding shade before the horizon-glass is now interposed and tried as the former one, and turned round exactly as before, until its effect is also perpendicular to the plane of the instrument. Leaving this latter shade untouched, and substituting the next dark shade in place of that first employed, the process is again repeated, with this caution, that the error, if any, caused by the prismatic form of the last shade, is to be made exactly contrary to that of the first shade, as well as perpendicular to the plane of the sextant. In this way, changing when necessary the dark glass at the eye end of the telescope, all the dark shades are carefully examined and set right, and it need not be said that those which are very prismatic or which affect the sharpness of the images, are to be rejected. The index-glass is now to be set at right angles to the plane of the instrument. This is done by looking very obliquely in the index-glass, when the edge of the limb or the divided arc seen by reflection will form an uninterrupted continuation to that seen directly, if the glass is perpendicular; otherwise the arc will appear broken where the direct and reflected images meet; by touching the screws seen in the figure, this error may be corrected. Repeating the observation at different parts of the limb, will show whether the axis has been set at right angles to the limb. The horizon-glass is to be made parallel to the index-glass by bringing the two images of the sun to coincide, when, if there is any lateral overlapping, it may be remedied by turning a screw (shown in the figure) which is in the mounting of the horizon-glass. The index error, as it is called, is of no importance whatever, though many observers are afraid that when large it vitiates the observation. This is an idle prejudice, but one which the maker is compelled to respect. Having ascertained the diameter of the sun by measuring it forwards and backwards, he sets the index to the proper angle and then files away a little of one of the pins against which the index-glass is pressed, until he brings the images nearly into contact. Contacts should now be formed, first by turning the tangent-screw so as to separate the images, and then by bringing them together. If the readings do not agree, the centre moves too stiffly or the index-bar is too weak. Finally, the telescope is to be set parallel with the plane of the instrument. There are two parallel wires in the focus of the telescope, which are to be placed parallel to the instrument, and then as large an angle as possible is to be taken between two distinct objects, making the contact exactly in the middle of the wires. The contact must now be examined when the objects are first at one side and then at the other of the field of view. If they separate equally when at equal distances from the centre, the position of the telescope is correct; if not, there are adjusting screws in the collar which carries the telescope by which this error may be corrected. For some of these latter adjustments mechanical means may be and sometimes are applied. The instrument should however comply with the foregoing tests, which any one can try who understands the use of the instrument.

We will now suppose an observer equipped with such a sextant, who wishes to make the best use of it. Before taking a series of observations, the index error should be ascertained. The telescope is fixed and set to focus, and the parallel wires placed parallel with the plane of the instrument. If the sun is visible, a dark glass for the eye-end of the telescope is selected, which shows him clearly, but without distressing the eye, and the direct and reflected images are made equally bright by moving the adjusting screw, which raises or depresses the telescope. The contact is first made, bringing the reflected image apparently below the image seen directly, and the angle is read off on the supplemental or back arc: suppose this reading to be 33′, which consider positive or +. Then make the contact again with the reflected image apparently above that seen directly (the reflected image is that which moves on moving the index), and read off again: suppose this is 32′, which call —. It is evident that at the middle position the two images coincide, and the index and horizon-glass are parallel; that is, the reading on the back arc is 30″ when the glasses are parallel. Hence 30″ must be *added* to every other reading to give the true angle. If the algebraical signs are used, the rule is very simple: Add the two readings together and halve the result; this with its *proper* sign is the *index correction* to be applied to all observations. If the sun is not visible, the moon may be used in the same way. If neither is to be seen, then bring the two images of a bright star, or the sea horizon, or any *distant* well-defined object into contact, and the reading, if on the back arc, is to be added, if on the forward arc, is to be subtracted from all other observations. The sun is always to be preferred when visible, and the observation is to be repeated before or after correction. If the images overlap laterally, that is, if the horizon-glass is not parallel to the index-glass, this must be previously adjusted. The next caution is with respect to dark glasses. When it is possible (as in observing altitudes of the sun at land in a mercurial horizon, &c.) to make the observation with a single dark glass on the eye-end of the telescope, without using any shade, this should always be done, for the error of this dark glass does not affect the contact at all, and the distortion caused by it is not magnified, whereas any fault in the dark shade between the index and horizon glasses produces actual error in the observation, and the distortion is magnified subsequently by the telescope. The images are to be brought to equal brightness by the screw which raises or depresses the collar carrying the telescope, and that with considerable nicety. In observing distances of the sun and moon, or altitudes of the sun at sea, dark shades are necessary. The fainter object is to be observed directly, and a proper shade interposed between the index and horizon glasses to reduce the two objects to something like the same brightness. The final equalisation is to be effected by the up-and-down motion of the telescope. The accuracy of the observation depends a good deal upon the nicety with which this equal toning of the two images is effected: with a little experience this is readily learned. From the construction of the sextant the faint object is easily viewed *directly* when the brighter object is either above or on the right hand of the fainter, but not so if the bright object is to the left of the fainter, when the handle side of the instrument is uppermost. For these observations, the instrument should have a second handle, which may be applied when wanted; perhaps when the distance between the moon and a bright star or planet is to be observed, there may be no difficulty in viewing the moon directly, after placing a dark shade before the horizon-glass, though the light which enters the eye without passing through the telescope must deaden the retina considerably. A blackened card screen slipped over the tube of the telescope would probably be found useful in this case, and absolutely necessary if the sun were observed directly. This latter observation cannot, we conceive, be satisfactorily made in any case. When the sextant is held in the hand, it should not be grasped tightly, as this causes tremor. The handle should be fitted to the observer's hand. There is scarcely ever hold enough given. When observing an altitude at sea, there is a little difficulty in bringing down the object to the point of the horizon immediately under it. But as the shortest distance is the true distance, by running along the horizon and keeping the object in the field, the direction in which the object should be observed is easily found, and the contact made there. In observing lunar distances the great art is to turn the instrument round the line of sight exactly as if the telescope were an axis of rotation. The index is set to the approximate distance, and the fainter object viewed directly; when the plane of the instrument passes through both objects, the brighter will come into the field, and the contact is to be made by the tangent-screw, or nearly so. We think it is better in all cases where the angle between the objects is increasing or decreasing, to make the contact open or close, and then try to seize on the moment when the contact is perfect, or the two moments when the contact begins and when you conceive it to end. The mean will probably be near the truth. All contacts must be made scrupulously in the centre between the two parallel wires. When the angle is large, inattention to this point will cause considerable error.

On shipboard, the observations, except those of lunar distance, are necessarily rude and imperfect, the sea horizon is generally ill defined and badly seen, the dip is somewhat uncertain, and as the single altitude is observed, all the error committed tells upon the final angle. The accuracy of observation is however equal to the wants of navigation in ordinary circumstances. (A *dip sector* might be useful where more than usual accuracy is required.) On land, where the altitudes are taken from a mercurial horizon, and the sextant fixed on a stand, the observation is capable of great accuracy, and does not require much skill or delicacy in mere handling. There is one peculiar advantage in sextant observations, that when the mercury is quiet enough to reflect a well-defined image, there is no need of any further steadiness or of a second observer, one of which conditions is absolutely necessary in every other instrument in common use which is adjusted by a plumb-line or level. We think the capabilities of the sextant as a geographical instrument have not been generally appreciated by English travellers; certain it is that few have used it with all the profit they might have done.

The mercurial horizon is a shallow rectangular wooden or iron trough, into which a small quantity of mercury is poured. If there is any wind, the trough must be covered with a penthouse, the sloping sides of which are glazed with plates of glass ground very flat and true. Any object seen in the mercury appears to be just as much below the horizontal plane as it is really above it; hence if the angle between any heavenly body and its reflection be measured, this angle is just twice the actual altitude of the body at that time above the horizon of the place. Suppose the altitude of the sun is to be observed in order to determine the time: The trough is placed with its largest dimension towards the sun, and the roof so that the sides cast no shadow, the proper dark glass is affixed to the telescope, the images brought to equal brightness, the index error ascertained, and the telescope is then directed to the image of the sun in the mercury. Holding the plane of the sextant vertical, and moving the index forward gradually, the image of the sun reflected by the index-glass will appear to enter the field from below. If the sun be rising, the index should be carried forward until the two images, having crossed, are clear of each other, and then the index is clamped. The two images will gradually close, and the exact moment by the chronometer is to be noted when the contact takes place. If the sun is rising with tolerable rapidity, the contact of the upper limb, that is, the separation of the two images, should be noted, exactly as before, without touching the clamp. The index is then read off; it may then be put forwards, and the observation repeated. If the interval between the contacts of the lower and upper limb is found to be in both cases nearly the same, the observer may be satisfied that he has committed no great error in noting the moments of contact. Where the greatest accuracy is required, it is usual to set the index to a whole number of degrees for the first pair of observations, and to put it forward 1° 30′ or 2° for the second pair, and so on till the observer is satisfied or wearied; and then in the afternoon to set to the highest reading for the first pair, and so on *backwards* till you arrive at the first reading. Collecting the corresponding pairs, you have an approximate time for apparent noon, which, after being corrected by the *equation to equal altitudes* for the change of the sun's declination, gives the time of *apparent* noon by the chronometer; and this, when corrected a second time by the *equation of time* taken and interpolated from the 'Nautical Almanac,' gives the time of *mean noon* by the chronometer, and consequently the error of the chronometer on mean time at the place. If the altitudes are very low, and the barometer and thermometer have changed considerably between the observations, a corresponding correction must be applied, but in most cases this is not requisite. The time may in this way be generally got as accurately as the chronometer will keep it during the interval. When observations of the sun are made for the latitude, the altitudes should be taken continuously for several minutes before and after apparent noon, observing the upper and lower limb alternately, or at least an equal number of each: thus getting rid of the sun's semidiameter, besides bringing more divisions into play. It is not easy to give a definite rule for the extent of these observations on each side noon; but when the time is known, and the altitude of the sun not great, we have never scrupled to go as far as the *Tables of Reduction*, that is, a good half hour on each side of the meridian. It is of great importance however, when the observations are pushed so far, that the number of observations on each side, and the times at which they are taken, should nearly correspond. If this precaution be observed, a slight error in the actual time of noon does not matter. When time is determined by absolute altitudes, the roof of the mercurial horizon should be reversed after half the observations, and the same precaution should be adopted when observations are made for the latitude. For equal altitudes it is necessary to keep the same position of the roof in both cases.

In the observations already described, and for lunar distances, a stand for the sextant will indeed add greatly to the accuracy of the observations, but is not absolutely necessary for a practised observer; so far as our own experience has gone, good observations of the stars can scarcely be made without a stand. By lying on the ground, and resting the edge of the sextant on a book or some convenient support, the observation may undoubtedly be made; but in most situations and in many climates this would expose the observer to more inconvenience and risk than he can prudently encounter. With a stand, and a little experience in setting it up, the observation of a star is just as accurate as that of the sun. The time is noted when the images form a figure like this **, parallel to the horizon; and stars of the third magnitude, or even lower, are quite bright enough for the purpose. We have observed Polaris very tolerably with a snuff-box sextant when the instrument rested on a book; the telescope, though of extra size for the instrument, was of much smaller aperture than those attached to ordinary sextants. It is rather steadiness which is required for these observations than light. Equal altitudes of the same star give the moment of its meridian passage by the chronometer without computation; and as this is the R.A. of the star, the error of the chronometer, if it be sidereal, is obtained at once; if it should be a solar chronometer, the computation is very easy, that is, merely computing the mean solar time of the star's transit of that day from the R.A. of the star and the longitude of the place. The computation of *circum-meridian* altitudes of a star for the latitude is rendered more simple by using a sidereal chronometer, for the hour angles observed with the solar chronometer must be reduced to sidereal time before taking out the corrections to the meridian from the Tables of Reduction.

There are certain faults either usual or inevitable in the sextant, which are now to be pointed out, and the mode of eliminating their effect from the final result. First, the determination of index correction is always somewhat erroneous, and this error runs through all the absolute observations, and affects the mean with its whole amount. Again, if the telescope be not parallel to the plane of the instrument, or if the contact be not made exactly midway between the wires, the angle read off is too large, and exceeds the true angle, and there is no principle of compensation; this class of errors has always the same sign. Finally, as sextants are now divided, there is no certainty that the axis of the index is exactly concentric with the divided arc. It is difficult to say within what limits this error is confined, but we think it amounts not unfrequently to 10″, 15″, or even 20″ in the total arc.[*] This is not, however, proportional to the arc, though it is generally smaller in the smaller arcs. Hence if this effect of excentricity lie the same way as the other errors, as it easily may, the most careful observer will make a considerable mistake in measuring a large angle. If we further suppose the error of the lunar tables to be in the same direction (the best meridian observations show that the moon is not unfrequently from 10″ to 15″ out of her tabular place), it will be seen that the longitude, determined as it generally is by distances between the moon and sun, or the moon and a *single* star, may differ much more from the truth than lunar observers usually think possible.[†]

Mere instrumental error is got rid of by combining those observations which they affect in contrary ways. Thus in equal altitudes, the *fixed* errors, such as index error, excentricity, bad division, inclination of the glasses or telescope, have contrary effects on the morning and afternoon sights, and therefore no effect on the mean. Making the contacts out of the middle of the wires is a casual error, and just as likely to happen in the morning as in the evening observations; so that as the angles are the same in both cases, errors of this kind will have pretty much the same influence on the mean of several pairs.

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[*] Mr. Simms is of opinion that with a dividing engine of a better construction, this error of excentricity may be reduced to 2″ or 3″.

[†] We think no prudent seaman would rely upon lunar distances at sea to a smaller quantity than one-third of a degree. At land a good observer should seldom be out more than an eighth of a degree; and a large mass of careful observations, corrected for the errors of the lunar tables, might perhaps come within the sixteenth or twentieth of a degree. This seems to us almost the limit of what is to be expected from lunar distances, and it is inferior in accuracy to one favourable lunar transit, with a tolerable telescope, a well practised observer, and a corresponding observation at a principal observatory.

Hence the great excellence of the method of equal altitudes for determining the time, so far as instrumental error is concerned; it is an additional advantage that an error in the supposed latitude is also without sensible influence. Again, if time is deduced by absolute altitudes of a star rising in the east, the result will be affected one way by the errors above described; if a second star be observed at nearly the same altitude setting in the west, the altitude will be affected to the same amount; and if the stars have declinations which do not widely differ, the result deduced from the second star will be affected to the same extent, but in a contrary way from the first; a mean of the two results will be nearly free from any error, except the casual error of observation. A latitude by the sun or a star to the south, which is erroneous from the above-mentioned causes, will be balanced and corrected by a star of nearly the same altitude to the north; or a star to the north may be balanced by two to the south, one of higher and the other of lower altitude. It is scarcely credible how nearly the time or latitude may be thus determined. We have a series of such latitudes with an 8-inch sextant, observed by Mr. Lassell at Liverpool, which scarcely differ more than 2″ or 3″ from each other, though deduced from different groups of Greenwich stars. When the longitude is to be obtained from lunar distances, a considerable number of observations should be taken from the objects east and those west of the moon. If a pair can be selected on different sides of the moon, and nearly at the same distance from her, the result will be liable to the effect of casual error only, and to the error of the lunar tables. This latter error cannot be got rid of at the time of observation; but after the Greenwich, Cambridge, Edinburgh, Cape of Good Hope, and Oxford observations for the year have been published, it will generally be possible to find the error of the moon at the time of observation with considerable accuracy. This must be done whenever a sure longitude is to be deduced from lunar distances, and lunar observations must be taken in great numbers, so as to destroy casual error, to settle nice points in geography.

When a few more fundamental points in longitude are fixed, it will not be necessary to use lunar distances, except in long voyages, or in the centre of large and uncivilised countries. The recent improvements in chronometers, and the reduction in their price, have greatly superseded this kind of observation already, and will continue to do so more and more.

When the arc of the instrument is limited to 90°, which is usually the case in the common wooden instrument, it is called a quadrant (and sometimes an octant, as being in form an eighth of a circle), and a second horizon-glass and sight are sometimes appended for the *back* observation. A sight-vane (a plate of brass pierced with a small hole) is placed below the ordinary horizon-glass, and a second horizon-glass is fixed near this vane, so that lines from the centre of the index-glass, and from the latter vane, make equal angles with its plane. The plane of this second horizon-glass should be at right angles with the index-glass, when the index is at zero. This adjustment may be verified by making the sea-horizon seen directly through the second vane and unsilvered part of the second horizon-glass, coincide with the sea-horizon at the back of the observer, which is seen by two reflections from the index-glass and silvered part of the second horizon-glass. The angle between the fore and back sea-horizons is evidently equal to 180° + twice the dip of the horizon. The dip is known from the observer's height above the sea-level. Suppose it to be 4′, and that the reading on the back arc is 5′; it should be twice the dip, or 8′: therefore the zero position of the index for the back observation is at 3′ on the forward arc. This may be corrected by altering the second horizon-glass, if there are the means of adjustment; that is, by making the front and back sea-horizon coincide when the reading is 8′ on the back arc. By moving the index forward, the reflected sun, which is behind the observer, can be brought to touch the sea-horizon in front; and the reading, when the index error has been corrected, is 180° — the sun's distance from the front horizon. Now this latter angle is evidently 180° + 2 × dip — sun's altitude; hence it is clear the angle read off is the sun's altitude above the horizon — 2 × dip. Hence sun's altitude — dip (the altitude required) = angle read off + dip. If the index error be not adjusted, the angle must be corrected for the index error; in the preceding instance the 3′ must be added to the sun's altitude. The back observation, however, though useful in certain circumstances, is not much used at present, and many quadrants are fitted up without the second vane and horizon-glass.

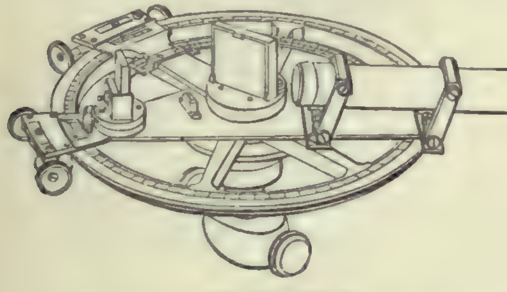
If a sextant be used in the manner we have attempted to describe, the results will be found to be very satisfactory. The attentive reader will see that the principle to be seized upon is that of always making two observations at nearly the same time, in which the errors, except the casual errors of making the contacts and of reading off, are the same, but the effects of which on the final result are different. It is not always convenient to afford the time which these balanced observations require; and, in fact, they are often impracticable. It will, therefore, be well worth the careful observer's while to determine the constant errors of his sextant, at different angles, where he has a good opportunity, and to use this knowledge where circumstances do not allow him to make a balanced set.

Very small sextants are sometimes fitted in a box, and are called *snuff-box* sextants. These admit of considerable accuracy; but, except in particular cases, they are not carefully adjusted, &c. The principle is, of course, the same as in the larger sextants, and they have a small telescope and dark glasses. It is desirable that the box should be wide enough to admit a finger to wipe the glasses, especially when the snuff-box sextant is used, as it frequently is, for maritime surveying. The salt spray very soon clouds the glasses, and there is no light to spare. For all sea-going purposes, except taking lunar distances, and for military and maritime surveying, the snuff-box sextant will be found very convenient and sufficiently accurate. If made with the utmost care, and skilfully used, we think it capable of determining the latitude within 1′, and the time to 3^s or 4^s; but an instrument-maker could not be expected to take so much trouble, unless for a favourite customer or for an expedition of some importance.

After the invention of Borda's repeating reflecting circle, Troughton, who was averse to the principle, produced a non-repeating circle, which he called the British circle; but it more commonly goes by his name. This may be understood by conceiving the circle, of which the sextant is a part, to be completed, and that while the telescope and glasses are at the front of the instrument, the divisions and three equidistant verniers attached to the index-glass are at the back. The observations ought always to be made in pairs, and for this purpose there are two handles, one to the front and another at the back. Thus, suppose it were required to take the altitude of the sun: this is first observed exactly as with the sextant, and the three verniers read off, the index-glass being above the line which joins the telescope and horizon-glass. Let the instrument be conceived to turn round this line through 180°, then the index-glass is below, and with the face downwards. By moving the index backwards to zero, it will become parallel to the horizon-glass, and continuing this motion until it is at the original angle, but *on the back arc*, the sun will be brought down exactly as in the former observation; when the contact is to be made with the tangent-screw, and the indices again read off. By combining the observations it is clear the index error is destroyed, and this is one point of superiority to the sextant. Again, the three readings wholly destroy any effect of excentricity, and very greatly diminish those errors which may arise from accidental injury to the figure of the circle, while the six readings greatly reduce the errors of division. The errors caused by defects in the dark glasses and horizon-glass are eliminated, and such as arise from a defect in the index-glass are diminished, and this too by the principle of the instrument, using it independently upon one object. These advantages are undoubtedly very great; but the additional weight of the circle and trouble in handling it, the trouble of reading three verniers for every observation, the shortness of the radius, and consequent necessity of limiting the subdivision to 20″, seem to overbalance them in the opinion of most seamen. We think that an intelligent observer will get results of nearly equal value from the sextant or from Troughton's circle, but that the sextant requires much care in selecting and balancing observations, which the circle does not. Whenever time or latitude is to be deduced from observations of one object at one time, as where the sun alone is used on geographical expeditions, or where lunar distances are taken from the sun alone, or from one star, the sextant cannot enter into comparison with the circle. A very excellent Spanish observer, Don J. J. Ferrer, determined the obliquity of the ecliptic with one of Troughton's circles more accurately than the Greenwich quadrant could do, at a time when that quadrant was still the principal declination instrument in the Royal Observatory. And if frequent reading off is not too great an objection, Troughton's circle may be recommended as the safer and more independent instrument, and as demanding less thought and care from the observer.

We have already, in the article REPEATING CIRCLE, described the original discovery of the principle by Tobias Mayer, and his first application of it. After Mayer had greatly improved the lunar tables, he proposed the following construction for measuring the angle between the moon and any other object with the greatest exactness. ('Tabulæ motuum Solis et Lunæ, auctore Tobias Mayer,' London, 1770.) The instrument is an entire circle, on the centre of which the index-bar turns, the index-glass being over the centre. The telescope and horizon-glass are fixed on a second bar, which also turns, but excentrically, on the same centre. The two bars can be clamped independently of each other, and each in any position, and there is an index or fiducial line to each, by which the divisions of the circle may be read off. Now, suppose a distance between the moon and sun to be required (the dark shades, &c., may be understood from what has been said on the sextant): First, having fixed the index-bar at zero, bring the horizon-glass to be parallel to it by observing the sun (as in determining index correction); then move forward the index-bar, and observe the distance between the moon and sun's nearest limbs, as with the sextant. If the angle were now read off, we should have the simple distance affected with the whole error of graduation, and obtain no advantage over the sextant. By moving the horizon-bar, bring the two glasses to be parallel exactly as before, and make the measure between the limbs of the moon and sun also as before, by moving the index-bar alone. The angle, if read off now, would be twice the angle required, but the errors of division and reading off would be only those which affect the first and last position of the index-bar. In this way the angle may be *repeated* as often as you please, until the bars have travelled once, twice, or even oftener round the circle; and it is evident that the errors of division and reading off are those at the first and last position of the index-bar, and those alone, which may be as inoperative on the measurement of the angle as the observer pleases or has patience for. This would seem a great advantage; but when Bird was ordered to make a circle on this model, the divisions were found to be so good that repetition added little to the accuracy of which a single observation was capable, and the fresh determination of a position of parallelism after every observation was too much trouble to be taken when not absolutely necessary. The reflecting circle of Mayer was not adopted in England, but great pains were employed in constructing and dividing the sextant, in which our artists were eminently successful.

In France it is probable that the art of instrument-making was at this time less advanced, and therefore the merit of Mayer's principle was more readily appreciated. The celebrated Borda, who was a seaman and navigator, first had an improved instrument on this construction made about 1775,[*] and published a full description of its form and use in 1787 ('Description et Usage du Cercle de Réflexion, par le Chevalier de Borda,' Paris, 1787), to which we refer the reader as a standard and classical work. The accompanying figure will explain Borda's instrument, though it is not precisely similar to that which he recommended.



Five-Inch Diameter.
Borda's Reflecting Circle, by Troughton and Simms.

The index-glass, with its bar, vernier, and tangent screw, and the excentric bar which carries the telescope, horizon-glass, with its vernier and tangent screw, require no explanation. The telescope has a parallel-ruler motion to bring the images to equal brightness, which is, we believe, Bird's construction. Borda holds his telescope by two ears, each of which can be raised or depressed separately, and he has a graduation for each, so as to move them equal quantities. Dollond, in his very beautiful repeating circles, has an up-and-down piece *above* the bar. The important and essential conditions of the repeating circle are, that moving one index shall in no way affect the other; that the clamps when fixed shall not be liable to move from looseness, bad balancing, or bad centering when the position of the circle is changed; and finally, that the axis of the index-glass and the collar on which the horizon-bar turns shall both be so true, and of such a length, that the motions of each bar are parallel to the plane of the divided circle. The same precautions must be taken as in the sextant in trying the index and horizon glasses, in placing the prismatic edges of the dark glasses up and down alternately, in setting the glasses perpendicular to the plane of the circle, and the telescope parallel to it: and it is scarcely necessary to add, that the directions given above for using dark glasses, equalising brightness, &c., apply to one reflecting instrument as well as another. The cells into which the dark glasses are inserted, when wanted, are seen between the two glasses and also in front of the horizon-glass.

On looking at Borda's circle as it is here represented, the opening of the angle between the two glasses is towards the spectator; hence an observer looking through the telescope would see an object directly in the line of the telescope, and some other object, call it A, which lies towards the spectator, by reflexion. Now suppose the index-bar to be moved through the position of parallelism and until the glasses make the same angle as before, but with the opening from the spectator, it is clear, first, that the angle read off between the first and second positions will be twice the original angle; and secondly, that the observer, still looking at the same object as before seen *directly*, will see by reflexion an object on his right hand (call it B), which makes the same angle with the axis of the telescope as A did, but on the other side. Now if we suppose the whole instrument to turn half round upon the telescope as an axis, it is evident that A will be seen exactly as at first, while the index-bar has been moved forwards twice the angle between A and the axis of the telescope produced. This is exactly the complete observation with Troughton's circle, and thus while we have got double the angle by two observations, we have got rid of index error, and have only two readings to which error of division and reading off can apply.[*] Now suppose the instrument to be returned to its original position, and, leaving the index-bar securely clamped, move the horizon-bar, which carries the telescope and horizon-glass, through the same angle and in the same direction as the index-bar has travelled. If the original object be again viewed through the telescope, and the contact between that and A perfected by the tangent screw of the horizon-bar, it is clear that everything is exactly as at starting, except that the index and horizon-bar have each moved over the divided circle exactly twice the angle to be measured. Let the operation which has been described be repeated, and everything will be as at starting, except that the indices will have moved over four times the angle, and it is evident that there is no limit to the number of repetitions except the will of the observer. So that, theoretically at least, the influence of bad division, bad centering, and bad reading off upon the final angle may be reduced below any sensible quantity. There is another very considerable advantage, namely, that there are only two readings off of each vernier † for any number of repetitions.

On looking at the figure again it will be seen that the rays of light which fall on the index-glass pass *between* the telescope and the horizon-glass, and there is a particular angle at which they pass through the horizon-glass before falling on the index-glass. This occasions some inconvenience, as the reflected image in that case is scarcely ever quite perfect, and if the sun be the reflected object, the interposed dark glass increases the imperfection. When Borda's circle is used in the hand for observing altitudes, the instrument is to be held alternately in the left and right hand for the crossed observations, but in taking lunar distances there is the same difficulty as in the sextant when the face is downwards. A handle with curved tube may however be applied pretty much as in Troughton's circle, and if it is fixed into a collar which turns on the centre, it may be kept out of the way of the telescope, &c. There is a part of this circle which, though not actually necessary, will be found of great convenience, the graduated semicircular arc which is attached to the horizon-bar. The index-bar, either by its edge or by a fiducial line, points out the reading on the semicircle, and shows 0 on each side when the glasses are parallel. By the help of this it is easy to set roughly to any angle on one side or the other, and thus save the trouble which nice setting would require, or seeking for an object, which is still more troublesome. In some circles two small pieces which slide easily can be fixed on this semicircle, and the proper opening is given by the touch alone, that is, when the index-bar just feels the stop. But there is always a risk of forcing a clamp which is supposed to be fixed, by the slightest touch, and therefore we prefer setting by a coarse-reading. As the chronometer must be noted and read off at every observation, there will generally be light enough for this purpose. Borda's original circles were much too large, and very weak and ugly. Six inches diameter seems to us quite sufficient for an instrument of this construction, which is intended to be used according to its principle. The telescope and glasses are nearly the same for all sizes, and the repetition reduces the errors of division and reading off so rapidly that we should prefer rather a coarse division, which is easily seen, to a fine one. A boldly cut division to 30″ would probably be best for general purposes; the circle should be as light as is consistent with strength, but the main points to be looked to are the independence of the index and horizon-bars, the truth and perpendicularity of the centerings, and the firmness of the clamps. Whether the want of balance in both bars, and especially the horizon-bar, is wholly innoxious, is a point of some doubt, otherwise there would seem to be no theoretical objection to a well-made repeating circle. Hitherto this instrument has not been much used in England. By some it may have been thought more troublesome than the sextant; it has generally been made too large and cumbersome, and perhaps prejudice may be added as one of the causes why it has not been properly valued. At the same time, though warm partisans of the repeating principle, we conceive that the results with a repeating circle will not be superior to those which *may* be attained by the sextant or by Troughton's circle when in the best hands; but it is more independent, requires less thought and care and skill than the sextant, and is neither so troublesome nor so cumbrous as Troughton's circle.

An alteration was proposed in Troughton's construction by Mr. Hasslar, director of the survey of the coast of the United States. The circle turns freely round the centre, and is clamped at pleasure either to the frame which supports the horizon glass and telescope, or to the index bar which carries the index glass. The arrangement is exceedingly ingenious, but we suspect that the clamping and unclamping must affect each other, notwithstanding the beauty of the workmanship They are also made much too heavy for the hand, and, considering the principle, unnecessarily so. Mr. Haslar employed them, we believe, in his survey, but we have not heard of their use elsewhere. The idea of a moveable or flying circle was probably taken from De Mendoza Rios, who proposed a flying vernier, as well as circle. ('Phil. Trans.' 1801, p. 362.) The complication of this construction, and the practical objections to it, were, we presume, fatal to its adoption; for we are not aware that it has ever been successfully used. In observing altitudes at sea, it is presumed that the horizon is always visible, which in hazy weather, or in dark nights, is frequently not the case. There have been several proposals for overcoming the difficulty by adapting a plumb-line or level to the sextant when required.

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[*] Borda's alterations were apparently very simple: he drew the telescope back until its object-glass fell short of the index-glass, while Mayer's projected beyond it, and he carried the horizon-glass forward almost to the edge of the circle, which Mayer planted close before his telescope. Yet these slight modifications completely changed the instrument.

[*] Some observers use the repeating circle as a sextant. They change the readings from time to time by altering the position of the horizon-bar and determining the zero position of the index-bar. This mode of observing will undoubtedly tend to destroy errors of division and excentricity, but it is a complete sacrifice of the best qualities of a repeating circle. At any rate index error should be destroyed in the way we have pointed out, which would be some compensation for the reduced radius of the divided arc. Borda calls the pair *observations croisées*, or *crossed observations*.

† The index-vernier is usually read off and the horizon vernier neglected. Lieutenant Raper has pointed out the following use of the second vernier. Place the glasses parallel and read off both verniers; then if you wish to measure two angles rapidly, observe one by moving the index-bar, and the other by moving the horizon-bar. In observing altitudes of two stars in uncertain weather and in maritime surveying, this recommendation may be of great service. Let the greater angle be first measured by moving the index-bar, then the angle moved over by the index-bar is the greater angle, and the difference between this angle and that moved over by the horizon-bar is the less angle.

Several modifications, additions, and supposed improvements have been made in this class of instruments, but none of sufficient importance to require notice here. The sextant and circle, such as we have described them, are sufficient for the cases which practically occur; and without disputing the ingenuity and even utility of certain modifications in peculiar and exceptional cases, we believe that there is little to be gained by such alterations as have been hitherto proposed.

For reducing observations made with reflecting instruments, we must refer to the usual works on nautical astronomy. The tables of Thompson, or Riddle, or Inman, or Raper, will afford sufficient information. Borda's memoir, already mentioned, should be carefully studied by every one who proposes to use a repeating circle; and Troughton's article CIRCLE, in Brewster's 'Edinburgh Encyclopædia,' will be found of great value, especially as a guide to the circle known by his name. We have ventured very frequently to modify their opinions and directions, and the intelligent reader may decide for himself.

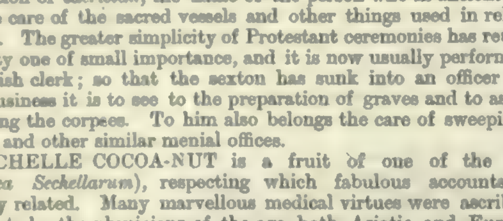
SEXTON, an officer of the church, whose name is supposed to be a contraction of *sacristan*, the name of the person who in ancient times had the care of the sacred vessels and other things used in religious services. The greater simplicity of Protestant ceremonies has rendered this duty one of small importance, and it is now usually performed by the parish clerk; so that the sexton has sunk into an officer whose chief business it is to see to the preparation of graves and to assist in depositing the corpses. To him also belongs the care of sweeping the church, and other similar menial offices.

SEYCHELLE COCOA-NUT is a fruit of one of the palms (*Lodoicea Sechellarum*), respecting which fabulous accounts were formerly related. Many marvellous medical virtues were ascribed to these nuts by the physicians of the age, both Asiatic and European, and they were consequently sold at a high price. At present they form only objects of curiosity, and are well-known under the name of double cocoa-nuts. To the inhabitants of the Seychelle Islands the tree is useful for its timber, which is hard externally, and employed in building their huts and for posts; the leaves and their footstalks are used for the roof, walls, and partitions, and for many other domestic purposes. The nuts weigh from 20 to 25 pounds each, and, when fresh, contain a white, transparent, and jelly-like substance, which is edible. The shells are employed in making vessels and dishes of various kinds, and the entire nuts form articles of commerce, as they are esteemed in other countries both for their fabled virtues and as curiosities.

SHADOWS, PROJECTION OF. [PERSPECTIVE.]

SHAGREEN. [LEATHER MANUFACTURE.]

SHAKE, in music, the alternate and rapid iteration of two sounds which are not less than a semitone, or more than a whole tone, apart. This grace—for as such it is considered—is generally introduced at a pause, and should commence rather slowly, and increase in rapidity as it proceeds, always concluding with a turn. Ex.:—

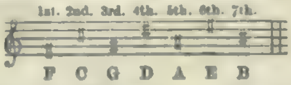


The *sign* of the shake is a *t* and an *r* conjoined, the two first letters of the Italian *trillo*, or the French *trille*, both signifying the same as the English term.

SHAKERS, a religious sect which arose in Lancashire about the year 1747. As the individuals of whom it at first consisted had previously been Quakers, they were sometimes called Shaking Quakers, but more commonly Shakers, from the violent shaking of their bodies in their religious exercises. In 1758 they were joined by Ann Lee, a native of Manchester, whose reputation gradually increased, together with the numbers of the sect, till, in 1770, she laid claim to divine inspiration, and called herself Ann the Word. In 1774, in consequence of the persecution to which they were subjected, she and some of her followers set sail from Liverpool for New York, where they arrived in safety. Ann Lee fixed her residence at Watervliet, on the Hudson, not far from Albany, and died at Watervliet in 1784. Their communities are called families. The property of each 'family' is held in common; and as the members, who are both males and females, are all single persons, celibacy being strictly enjoined, the numbers can only be kept up by converts. They are generally distinguished for good conduct in the common business of life. They agree with the Quakers in their abhorrence of war, their objection to take oaths, and in the belief of the direct influence of the Holy Spirit. Instead of the original violent shaking, they now move round their hall of worship in a regular and uniform dance to the singing of a hymn, clapping their hands in unison. There are some of the sect yet in Great Britain. No statement of the numbers of Shakers is given in the last census reports of either Great Britain or the United States; but several years ago there were said to be 6000 Shakers in the United States, comprised in fifteen 'families,'

SHAMOY. [LEATHER MANUFACTURE.]

SHARP, a character in music (♯), used to raise, by the degree of a semitone, any note in the natural scale. Before the character of the *natural* was introduced, the sharp was also employed to contradict the flat. When sharps are placed at the clef, they are always taken, according to the number required, in the following order:—



The DOUBLE SHARP, the character for which is a cross (×), is used in chromatic music, and raises a note two semitones above its natural state. Thus C *double sharp*

is, practically—though not strictly so in theory—D natural. [FLAT.]

SHAWL MANUFACTURE. The Hindoos have been the instructors of our manufacturers in the production of shawls. There are two modes of working the pattern in an Indian shawl; the one by embroidering it *upon* the material, and the other by working it *into* the web during the process of weaving. The first mode is a sort of needlework, and forms the less valuable kind of Indian shawl. In the production of the more costly kind, a number of skewers made of ivory or wood, about the size of a common packing-needle, are used; they are sharpened at both ends, and covered with different coloured wools. With these simple aids, the pattern is worked stitch by stitch into the web. The backs of these shawls show the effect of this minute and laborious handicraft, and present a totally different appearance from the European shawls, the patterns of which are woven entirely on the loom. These Indian shawls are mostly made from the inner hair of a goat reared on the dry cold table-land of Tibet, obtained after the long shaggy outer hair has been removed. No hair obtained from goats reared elsewhere has ever equalled this. Each goat yields about 2 lbs. per year. The best hair sells for 1 rupee per pound in Tibet. The wool is worked up into shawls in Cashmere, Lahore, and Delhi; especially the first named. Sometimes a sum equal to 300*l.* English will be given for a real Cashmere shawl.

Paisley excels all other towns in the United Kingdom in the manufacture of shawls, in quantity and (with one exception) in quality. The common kinds are woven in the power loom; while the finer kinds require the more detailed aid of the hand loom weaver. In the common shawls cotton is mixed with the wool; but for the finer articles the best wool of Germany, of Australia, and even of Cashmere, is employed. Some of the finest of these shawls are equal to anything produced in any other country. The Paisley weavers are mainly dependent on French patterns, which they modify in details; but the School of Design in that town is gradually training up a corps of designers whose taste may influence in an important degree the shawl manufacture.

The *printing* of shawls has not been much attended to until within the last few years; but now this art is carried to a very high pitch of excellence. At first it was adopted only for the commoner kinds of Scotch shawls. Red woollen shawls, printed in black designs for borders and centres, were at one time much in vogue. Then came imitations of them in cotton dyed Turkey red. Then chintz styles, upon white and light-coloured grounds. Next came in a fashion of printing the warp threads before the weaving. At length the manufacturers succeeded in producing blocks which would imitate the elaborate Cashmere pattern; this gave a great impetus to the printed shawl trade. Many establishments in Scotland now attend to this branch of manufacture, and strive to obtain new and good designs. The principal shawl-printing establishment in England is at Crayford in Kent, where as many as a hundred blocks, and sixteen hundred printings, or applications of the several blocks, have, in some instances, been necessary for the production of a single pattern. What an amount of labour is here involved, may be seen by referring to CALICO PRINTING.

SHEATHING. Owing to the great expense of copper sheathing, which has the effect of limiting its use in mercantile shipping, many attempts have been made to substitute for it either other metals, or alloys in which it is mixed with cheaper metals, or with such as might increase its durability. Mr. Robert Mushet directs that 100 lbs. of copper should be alloyed either with 2 oz. of zinc, 4 oz. of antimony, 8 oz. of arsenic, or 2 oz. of grain-tin; or instead of using one of these separately, that the whole be used together in the proportion of half an ounce each of the zinc and tin, 1 oz. of the antimony, and 2 oz. of the arsenic, to 100 lbs. of copper. By these mixtures, Mr. Mushet states that the copper is rendered much more cohesive and fibrous in its texture, and that the corrosive effect of the sea-water is in a great measure prevented. The metallic sheathing patented by Mr. Pope, consists either of tin and zinc, or of tin, lead, and zinc. If the former mixture be used, the zinc is first melted, an equal quantity of tin is added to it, and the alloy, after being stirred while fluid, is cast into cakes about three-quarters of an inch thick, which are hammered or rolled out to the required degree of tenuity. In uniting tin, lead, and zinc, the lead is first melted, double its quantity of tin is then added, and the alloy is cast into small lumps. A quantity of zinc equal to the tin and lead united is then separately melted, and the alloy of tin and lead is added to it; the whole, when thoroughly incorporated, being cast into cakes as before, for subsequent rolling out into sheets.

Iron, protected by the galvanic action of zinc, has also been used for sheathing. Mr. Pattison proposed to use sheets of iron similar in size to the sheets of copper sheathing, each having at its lower extremity a sheet of zinc from one-eighth to one fourth of an inch thick, attached in such a way that in sheathing the vessel from the upper part downwards, each succeeding sheet of iron shall be in contact with, and overlap, the zinc plate of the sheet immediately above it. Washers or perforated discs of zinc are also applied under the heads of the spikes or bolts used in fastening the sheathing; and the heads of the nails employed are made hollow, and filled with melted zinc.

Sheathing of brown paper coated with tar, and of various other non-metallic substances, has also been used. Perhaps the most important of these is a kind of felt, into the composition of which a considerable quantity of cow-hair enters. As this material itself felts very imperfectly, the sheets are passed, in the process of manufacture, through a boiler of pitch or tar, which increases the cohesion of the fabric. This material, which is sometimes used in conjunction with copper sheathing, being laid on immediately beneath it, has the important qualities of being a perfect protection against the worm, and of being at once impermeable to water, and so extensible as not to be easily broken by the working which takes place among the timbers of a crazy ship. A sheathing composed of a coarse fabric of fibrous material, saturated with a solution of caoutchouc, together with pitch and tar, has been recommended as a cheap and effectual substitute for felt.

Copper sheathing is usually applied in sheets about four feet long and fourteen inches wide, the thickness being such that a square foot weighs from sixteen to thirty-two ounces,—most commonly from twenty to twenty-eight ounces; and the mode of application does not vary materially whether the copper be laid upon the bare planking or upon an interposed layer of tarred paper, felt, or thin boarding. The sheets are pierced with holes, not only round the edges, but also at intervals of three or four inches over the whole surface; they are laid so as to overlap each other about an inch, and are secured to the ship with flat-headed copper-nails. Great regularity is observed in the arrangement of the sheets, so that a certain symmetry of appearance, as well as durability, is attained. After two voyages to the East Indies, or an equivalent amount of voyaging elsewhere, the coppering requires to be renewed; and the old copper is found to have lost three or four ounces of its weight in the square foot, by the action of sea-water, friction, and other causes.

All the copper sheathing for the Royal Navy—that is, for the ships built at the royal dockyards—is made at an establishment called the metal mills, in Chatham Dockyard.

SHEERS, or SHEARS, a contrivance used for hoisting the masts of a ship into or out of their place, and occasionally for loading and unloading heavy goods. The sheers used in masting vessels consist of two large poles, the lower ends of which rest upon thick planks laid along the sides of the deck; while their upper ends are lashed together so as to cross each other exactly over the hole in the deck through which the mast is to be dropped; they being sustained in this position by ropes radiating from the top to various parts of the vessel. To this apparatus is attached the tackle necessary for lifting the masts out of the water, when they have been floated to the side of the ship, and lowering them gently into their places. This is the apparatus commonly employed in masting merchant-ships; but the like operation is sometimes performed by means of a *sheer hulk* and sometimes by a *masting-house*. The *sheer-hulk* is an old man-of-war cut down to the lower deck, having a mast fixed in the hulk, and four stout spars or sheers which project obliquely from its side. The tops of these sheers reach to such a height and project to such a distance from the side of the hulk, that the vessel to be masted can come beneath them to be fitted with her lower masts. A *masting-house* is a lofty building erected for the purpose of performing the operation more conveniently, by the aid of mechanism overhanging the water to a considerable distance, beneath which ships may be floated.

SHEET-METAL. [COPPER; IRON; LEAD; TINNING AND TIN PLATE.]

SHEKEL (שֶׁקֶל), the principal weight and coin of the Hebrews. The subject of Hebrew weights and money is involved in great obscurity. The almost uniform testimony of ancient authors is that the shekel was equal to the Attic tetradrachm, or to the stater, or half the Roman ounce, that is to 4 denarii, which were reckoned at the period equal to four Attic drachmæ. The Septuagint indeed commonly renders the shekel by the didrachm current at Alexandria, which was double of the Attic. Hesychius, in one passage, makes it equal to four, and in others to two Attic drachmæ; and Suidas makes it five drachmæ. But the testimony of Hesychius and Suidas is of no value against that of St. Matthew, Josephus, Philo, and the other contemporary authorities. The average weight of the shekels of Simon Maccabæus is about 218 English grains, or half the English avoirdupois ounce, and only two grains more than the Roman ounce, or the weight assigned to the shekel by ancient writers. But the full weight of the Attic tetradrachm, to which the shekel is said to have been equal, was not the full one of 266 grains of the time of Pericles or Xenophon, but the reduced one under the Roman emperors, which was always considered as equivalent to the four denarii.

With respect to the shekel of the time before the Captivity, we have no certain information. The Rabbins say that after the Captivity all weights were increased by one-fifth; but there are many circumstances which prove this tradition to be of no value. In the absence of trustworthy information to the contrary, it is most probable that the ancient and the modern shekel were of the same weight, namely, about 218 grains.

The shekel formed the foundation of the Hebrew weights, of which there were three principal denominations: the shekel (שקל) meaning *weight*; the maneh (מנה), *number*, that is, a certain number of shekels or weights; and the kikkar (ככר), *a round number*, or *sum total*, that is, a certain collection of manehs, translated by the word "talent" in the Septuagint, Vulgate, and modern versions. The shekel, maneh, and kikkar corresponding respectively to the stater, mina, and talent.

The kikkar was equal to 3000 shekels. (Exod. xxxviii. 25.) There is a difficulty about the maneh, since from 1 Kings x. 16, compared with 2 Chron. ix. 16, it would seem to have contained 100 shekels, while in Ezekiel xlv. 12, it is ordered to contain 60 shekels. There are great difficulties in adopting the former value, and on the other hand the meaning of the passage in Ezekiel is very doubtful. If the latter value be adopted, the kikkar would contain 50 manehs. The shekel was subdivided into the beka (בקע, *half*), or half-shekel, or didrachm, the raba (רבע, *quarter*), or quarter-shekel, or drachm (the zuz or suza of the Talmudists), and the gerah (גרה, *a kind of bean*), or the twentieth of the shekel, or obolos. The following table therefore represents the Hebrew weights:—

Name	Value in Shekels.	Value in English Averdupois Weight.*		
		lbs.	oz.	grs.
Gerah	0$\frac{1}{20}$	0	0	10·94
Reba or Zuza . . .	0$\frac{1}{4}$	0	0	54·71
Beka	0$\frac{1}{2}$	0	0	109·43
Shekel	1	0	0$\frac{1}{2}$	
Maneh	60?	1	14	
Kikkar or Talent . . .	3000	93	12	

There appear however to have been at least two standards of the shekel, the *shekel of the sanctuary* and the *royal* or *profane shekel*. (Exod. xxx. 13; 2 Sam. xiv. 26.) The former was used in calculating the offerings to the Temple, and all other sums connected with the sacred law; the latter, for the tribute and civil payments. The tradition of the Rabbins is that the shekel of the sanctuary was double the profane shekel. By comparing the passages in Kings and Ezekiel quoted above, understanding the former of the profane shekel, and the latter of the shekel of the sanctuary, the process gives 100 : 60 or 5 : 3 for the ratio of the shekel of the sanctuary to the profane shekel.

The currency of the Jews from the earliest ages was silver, and this word expressed money. It is, however, nowhere mentioned as coined, but always as weighed out, till after the Captivity (Josh. vii. 21; 1 Kings xx. 39; Ezek. xlv. 15; Zechariah xi. 12), although some stamps appear to have been impressed on the ingots (Gen. xxiii. 16), or they were made up in the shape of rings, or *nezem* (Job xlii. 11, Septuagint). Gold money is first mentioned in David's time (1 Chron. xxi. 25; Isaiah xlvi. 6) under the name of אדרכון, *adarkon*, or דרכמון, *darkemon*, supposed to be gold darics, or drachms, neither of which however were in existence at the period, although both were probably current when the Chronicles were written or revised. The earliest Hebrew coins are the silver shekels of Simon Maccabæus, to whom the right of striking money had been conceded by Demetrius II, or Antiochus VII. (1 Maccab. xv. 6). These have on one side the supposed pot of *manna*, or, rather, gold and gemmed sacred vessel given by Simeon (1 Maccab. xiv. 15), with the legend שקל ישיאל, *shekel Ishrael*, "the shekel of Israel," and the initial letters of the year; and, on the other, the supposed Aaron's rod which budded, or, rather, the lilly of the valley of Israel (Isaiah xxxv. 1), and the legend ירישלים הקדישה, *Jerusalem haqodesha*, "Jerusalem the holy." The half shekels have the same types and legends, with *khatzi*, half, added to the word shekel. The inscriptions are in the Samaritan, and not in the square or Chaldee form, as it is called, of the Hebrew. No shekels of this dynasty are known later than the fourth year, after which the right of coining silver was suppressed, the Idumean line only issuing small pieces of copper; but there are later shekels of Barkozib or Barchochebas, who revolted under Hadrian, of broader and flatter shape, having on one side the wheatsheaf, or, rather, lulav, composed of palm, olive, and myrtle branches, with the legend ירושלם, Jerusalem, and on the reverse the beautiful gate of the temple, with four Doric columns and a star, allusive to the star of Jacob, with the legend שנת אחת לגאלת ישראל, *shenat akhat legulat Ishrael*, "the year one of the redemption of Israel," in a later form of Samaritan: these weigh 213·4 grains. The same Barkozib also recoined Roman denarii, for *rabas*, or quarter shekels, with a bunch of grapes on one side and the legend שמעון, Simeon, and on the other two trumpets crossed, or a lyre with לחרות ירושלם *lekharut Ishrael*, "the liberty of Israel."

It is as well to mention here that all pretended shekels or half shekels, with inscriptions in the square characters, are modern forgeries of the last two centuries, made by Dutch and German Jews for the purpose of deceiving the unwary collectors of ancient coins. According to the Rabbi Raschi the shekel was the same as the Tyrian of 24 obols or main, but St. Jerome (in Mica. proph. v. 14) makes the shekel equal to 20 obols, or 4 rabas of 5 obols each: 20 *geraks*, the supposed largest bronze coins of the Hebrew series, went to the shekel; and the gerah itself was subdivided into the *khatsi* or half, and *raba* or fourth, both of which expressions are found on the copper coins. There is a supposed third of a shekel, but it appears a nominal sum paid for the capitation tax, Nehem. x. 32, after the captivity. There is some difficulty in deciding upon what standard the shekel was adopted; the ancient Egyptian *kati* or *sati*, of 140 grs., by no means corresponds, and the Phœnician seems too heavy, although the weight is said to correspond with the tetradrachms of Antiochus VII. struck in Phœnicia.

If we assume that the standard was about the same as that of the Roman money, namely, $\frac{1}{30}$th of the weight alloy, the shekel of half an avoirdupois ounce would be equivalent to 210·983 grains of pure silver, or $\frac{210\cdot983}{80\cdot7}$ of a shilling, that is, to 2*s.* 7*d.* 1·49 farthings. According to this calculation, the following table represents the value of the Hebrew money:—

				£	s.	d.	farthings.
Gerah . . .	=	$\frac{1}{20}$ shekel	=	0	0	1	2·27
Reba . . .	=	$\frac{1}{4}$ „	=	0	0	7	3·36
Beka . . .	=	$\frac{1}{2}$ „	=	0	1	3	2·72
Shekel . . .	=		=	0	2	7	1·49
Maneh . . .	=	60 shekels	=	7	16	10	·8
Kikkar or Talent .	=	3000 shekels	=	396	5	10	

(Hussey, *On Ancient Weights and Money*; Winer, *Biblisches Realwörterbuch*, art. 'Sekel;' Calmet's *Dictionary*; Jahn, *Archäol. Bibl.*; Jennings's *Jewish Antiquities*; Cavedoni, *Numismata Biblica*, 8vo., Modena, 1850; De Saulcy, *Recherches sur la Numismatique Judaique*, 4to., Paris, 1854.)

SHELL, a hollow globe of iron, containing gunpowder, which is introduced at an orifice formed in the ball. In this orifice is driven or screwed the fuse or tube containing the composition by which the powder in the shell is ignited [FUZE]; and the shell, after being discharged from a gun, howitzer, or mortar, is consequently made to burst in pieces when it falls upon or near the object to be destroyed. The diameters of shells for guns vary from 3¾ inches to 10 inches, and the weight of a 10-inch shell is 70 lbs. The diameters of shells for mortars and howitzers vary from 4⅖ to 13 inches, and the weight of a 13-inch shell is 200 lbs. The diameters for carronades, which are now never used, varied from 3¾ inches to 8 inches. [BOMB; CASE-SHOT; SHRAPNEL-SHELL.] The shells for RIFLED ORDNANCE are described under that head.

SHELL-LAC. [LAC.]

SHELLS, *Economical uses of.* Shells are applied to several useful purposes, and to still more of an ornamental character. Some of them furnish dyes and pigments. The *purpura* contain an intense purple dye, in a few drops of liquid enclosed within a vein or sac in the fish. The *murex* yields various shades of purple and crimson. The *cuttle-fish* supplies the well-known sepia, of intense blackness. The beautiful substance called *mother-of-pearl* is described under PEARL FISHERY. The large proportion of lime in many shells renders them useful in making cement, and also as a fertiliser in agriculture. Shell-sand, produced by the natural crumbling of shells on the sea-shore, gives moderate fertility to many spots otherwise barren. Ground cockle and mussel shells are sometimes used as a covering for gravel walks. *Cowry* shells, inexhaustibly abundant on the shores of Asia and Africa, are used in India for the purposes of money, at an average value of about 200 for an English penny. The same cowries may be converted into a glaze for earthenware, and an enamel for clock-faces. A calcareous spongy plate found in the cuttle-fish is used by workmen as a substitute for emery-paper or sand-paper. The *conch* shell is in some countries used as a horn or trumpet; as in the West Indies, where on some plantations the negroes are summoned to work by a "conch-blow." The *haliotis* has an iridescent surface which fits it for use as a substitute for mother-of-pearl in inlaid work. The *helmet* shell supplies pieces large enough for umbrella-handles; and thinner portions as ornaments for workboxes and other trinkets. Smoked films from oyster-shells are used for large coat-buttons. The *clam* shells, often of very large size, are used in Roman Catholic countries as receptacles for holy-water; while some, perfectly white, are cut up for arm-rings and other ornaments. The fibres with which many kinds of shell-fish attach themselves to rocks, such as those of the *pinna*, are fine and strong enough to be worked up in the manner of silk. The *chank* shells of India are cut up into bangles, armlets, bracelets, anklets, finger-rings, toe-rings, &c., sometimes carved and gilt, or otherwise decorated. The fishery of chank shells, off Ceylon, is a very valuable one; seeing that some of the choice specimens are valued at their weight in gold. [CEYLON, in GEOG. DIV.] *Shell cameos* are noticed under CAMEO.

Considered as a working material, all shell is placed in one or other of two categories, *porcelanous* or *nacreous.* The porcelanous shells contain much lime and little animal matter; they are brittle, translucent, smooth, and not easily cut, and much resemble the enamel of teeth. They can only be worked on the lapidary method, with small grinding wheels. The nacreous shells, partaking of the nature of mother-of-pearl, contain less lime and more animal matter; they are tougher, softer, and iridescent; they may be easily sawn, scraped, and filed; and can then be polished with sand or pumice and water. [LAPIDARY WORK.]

SHERBET, as made in Persia, Turkey, and other eastern countries, is a beverage composed chiefly of water, lemon-juice, and sugar, with the addition of other ingredients to render it more pleasant to the taste; such as the pulp of fruits, perfumed cakes, amber, rose-water, &c.

SHERIF, an Arabic word which means "noble, illustrious," and a title given throughout Arabia, Egypt, and Barbary, to those who are descended from the Mohammedan prophet. In Turkey they are called amirs, that is, princes, and enjoy great privileges, such as not being subject to the payment of taxes; not being obliged to appear before a judge, unless he be one of their class; wearing a green turban and slippers; occupying a superior place in the mosque, &c. As men and women of this caste often contract marriage with persons who are not members of the same, and the title of sherif is inherited from either of the parents, the number of persons who enjoy this distinction has become very considerable in Turkey, Syria, and Egypt, where they may be found employed in the lowest offices. It is one of the privileges of Mecca to be governed by a sherif of the posterity of Hasan, son of Ali Ibn Abí Talib, which family enjoys the sole right to the throne. His dominions comprehend, besides the capital, Mecca, Medina, Jambo, Tayif, Sadie, Ghunfude, Hali, and thirteen other smaller districts, all situated in the Hejáz. His principal revenue consists of a tax imposed upon every pilgrim, and the presents made by Mohammedan princes.

SHERIFF, the Shire-Reve (scyr-gerefa), from the Saxon word *reafan*, "to levy, to seize," whence also greve. The German word is *graf*. The gerefa seems to have been a fiscal officer. In the Saxon period he represented the lord of a district, whether township or hundred, at the folkmote of the county; and within his district he levied the lord's dues, and performed some of his judicial functions. (Palgrave, 'Rise and Progr.,' i. 82.) He was usually not appointed by the lord, but elected by the freeholders of the district; and (accompanied by four of them) was required to be present on its behalf, as well as on the lord's, at the folkmote or county court. In like manner the Saxon prince or king employed in the shires or larger districts his gerefa or reve, who levied his dues, fines, and amerciaments; to whom his writs were addressed; who exercised on his behalf regal rights in the shire, for the preservation of the peace and the punishment of offenders; presided over the courts-leet or views of frankpledge, and (at least in the absence of the earl in ancient times, and since the Conquest instead of the earl) presided over the hundred and county courts. It is difficult to determine how far the functions of the sheriff were concurrent with and how far derived from the ealderman or earl of Saxon and Danish times; and the confusion between these offices has been increased by the translation, in our ancient laws, of the word sheriff in the Latin into *vice comes*, and in Norman French into *visconte* or *viscount* (deputy of the earl); whereas certainly many of the sheriff's powers even in Saxon times were derived from the freeholders, or from the crown alone, and the word graf (gerefa) in German was equivalent to our earl. That before and for a century after the Conquest the sheriff had powers independent of the earl, is obvious from the fact, that in the circuit (tourn) which he made periodically (Spelman's *Gl.*, 'Vice Comes') of his shire for the administration of justice (as the Saxon king made a circuit of his realm), he was accompanied not only by the freeholders, but by the bishop, the earl, and barons, until these noblemen were exempted from the duty by statute 52 Henry III., c. 10, A.D. 1267.

Sometimes the shrievalty, by grant of the crown, was hereditary; it was also often held for life, or for many years, and there were sometimes more sheriffs than one in a county, the persons chosen for the office being, according to Spelman, "totius regni proceres:" but the sheriff was usually chosen by the freeholders of the shire. The statute 28 Edward I., c. 8, which says that "the king hath granted unto his people that they shall have election of their sheriff in every shire (where the sheriff is not fixed in fee) if they list," is rather declaratory of the people's right than a grant of a new privilege. By the 14 Edward III., c. 7, it is enacted that no sheriff tarry in his bailiwick more than a year, and then another, who hath land sufficient in his bailiwick, shall be ordained on the morrow of All Souls, 3rd November, by the chancellor, treasurer, and chief baron of the exchequer, taking to them the chief justices of either bench if they be present. This was the law also, till quite recently, regarding under-sheriffs; but it has now been altered.

At present the crown in most cases appoints the sheriffs, and also fills up any vacancy which is occasioned by the death of a sheriff during his year of office. To some corporations of cities which are counties of themselves charters have given the power to elect their own sheriffs; the city of London has the right to elect the sheriff of Middlesex. In the county of Durham the bishop was sheriff until he was deprived of palatine powers in 1836; and in Westmoreland the office was hereditary in the family of the earl of Thanet as heir-general of the Viponts, to whom the shrievalty was granted by king John, until the death of the last earl, when it lapsed to and was subsequently by statute vested in the Crown. The annual appointment of sheriffs is now, in most counties, made thus:—On the morrow of St. Martin (12th November), the lord chancellor, first lord of the treasury, and chancellor of the exchequer, together with all the judges of the three courts of common law, meet in the exchequer chamber, the chancellor of the exchequer presiding. The judges then report the names of three fit persons in each county, and of these the first on the list is chosen, unless he assigns good reasons for exemption. The list thus made is again considered at a meeting of the Cabinet held on the morrow of the Purification (3rd February), at the president of the council's, and attended by the clerks of the council, when the excuses of the parties nominated are again examined, and the names are finally determined on for the approval of the queen, who, at a meeting of the privy council, pierces the parchment with a punch opposite the name of the person selected for each county; and hence has arisen the expression of "pricking the sheriffs." The judges of assize annually add the requisite number of names to their lists by inserting those of persons recommended by the sheriff going out of office.

The sheriff derives his authority from two patents, one of which commits to him the custody of the county, and the other commands the inhabitants to aid him. He takes an oath of office, the greater part of which relates to his collection of the crown revenue, and he gives security to the crown that he will duly account. He then appoints an under-sheriff, by whom in fact the duties of the office are performed. These duties are various and important. Lord Coke quaintly says that the sheriff has a triple custody—1st, of the *life of justice*, because to him are addressed the writs commencing all actions (all of which are now abolished), and he returns the juries for the trial of men's lives, liberties, lands, and goods; 2ndly, of the *life of the law*, because he executes judgments of the courts; and 3rdly, of the *life of the republic*, because he is in his county the principal conservator of the peace. By Magna Charta he is prohibited from holding pleas of the crown. He presides at all elections of members of parliament and coroners, and hence he cannot during the year of his office be elected a knight of the shire. He apprehends all wrong doers, and for that purpose, in criminal cases, he is entitled to break open outer doors to seize the offender; he defends the county against riot and rebellion or invasion [LORD LIEUTENANT], and to this end may require the assistance of all persons in it who are more than fifteen years of age, and who, when thus assembled under the sheriff's command, are called the *posse comitatûs*. [POSSE COMITATUS.] To refuse to the sheriff the aid which he requires is an offence punishable by fine and imprisonment. The sheriff takes precedence of all persons in the county. He seizes all lands which have fallen to the crown, and levies all fines and forfeitures; but he is not permitted to act as a justice of the peace. He executes many of the writs that issue from the superior courts, and all writs of execution; he is likewise responsible for the execution of criminals. He receives and entertains the judges of assize, on whom he is constantly in attendance whilst they remain in his shire.

To assist him in the performance of his duties, the sheriff employs an under-sheriff and also a bailiff and jailers, from whom he takes security for their good conduct. He is prohibited by very ancient statutes from selling his office or the profits of any part of it.

The liability of the sheriff for breach or neglect of his duties is a frequent sort of litigation. Few assizes occur without actions being brought against him for illegal arrests or levies, or for wrongfully abstaining from executing the process addressed to him. Thus the decisions affecting him are numerous and complicated, and there are many treatises concerning the office.

SHERIFF (SCOTLAND). In Scotland the duties of the sheriff are not, as in England, almost entirely executive. He exercises an extensive judicial authority, and a large portion of the general litigation of the country proceeds before this class of local judges. In earlier times his authority appears to have been merely of an executive character, and, appointed by the crown, he was the person to whom the royal writs, issuing from the supreme courts, were usually directed. He was the ordinary conservator of the peace within the local limits of his authority. He was an important fiscal officer, having in the general case the duty of levying the feudal casualties, forfeitures, and other items of revenue; and by statute he was vested with the power of mustering the military force of the country to the weapon-showing. In very early times, his tenure of office appears to have been limited by the grant; at a period comparatively later, the office became, in the general case, hereditary. The act for abolishing heritable jurisdictions in Scotland (20 Geo. II., c. 43), was passed for the purpose of abolishing all those remnants of the feudal courts of Scotland which were hereditary, or in any other shape of the nature of property; of bringing all judicial offices within the appointment of the crown, and their holders under responsibility to the public. By the same statute, the sheriff is authorised to appoint one or more substitutes; and at the present day there is a substitute in every county, and in the larger counties there are two or more. Both the sheriff and his substitute are lawyers, but the latter is the local resident judge, the former generally frequenting the courts in Edinburgh, where he hears appeals from his substitute, and making occasional visits to his county. By the Jurisdiction Act it was provided that each sheriff should reside in his county during four months in each year; this provision fell into desuetude, until by the 1 & 2 Vict. c. 119, it was enacted that each sheriff should remain in attendance on the court of session, but should hold eight courts in his county during the year. The sheriffs of Edinburgh and Lanark are exempted from attendance on the court of session, in the understanding that the business of their respective courts is sufficient fully to occupy their time.

In civil questions an appeal lies from the sheriff-substitute to the sheriff, but wherever the former is a sound lawyer and an industrious man, the privilege is seldom used. From the state in which the profession of the bar of Scotland has been for many years past, several of its members have been induced to accept the office of sheriff-substitute as vacancies have occurred. Formerly the office fell to country practitioners, who, not quite contented with the emoluments, eked them out by private practice; a state of matters seriously detrimental to the equal administration of justice. In some instances, even retired officers in the army or unprofessional country gentlemen were the best qualified persons who would undertake the office. No sheriff-substitute can now act as a law-agent, conveyancer, or banker; he is not removable, except with the consent of the lord president and lord justice clerk of the court of session, and must not be absent from his county more than six weeks in one year, or more than two weeks at a time, unless he obtain the consent of the sheriff, who must then act personally or appoint another substitute. In one or two instances, as in that of Kirkcudbright, the person who exercises the function of sheriff is called the Stewart. This designation owes its origin to certain peculiarities of territorial tenure which cannot be briefly explained and are subject to doubt and dispute. After the Reformation, the sheriffs were generally appointed commissaries of the local commissariat districts which most nearly conformed with their respective jurisdictions, and in 1823 (4 Geo. IV. c. 97) the commissariat functions were appointed to be merged in those of the sheriff.

The jurisdiction of the sheriff in civil matters does not extend to questions regarding heritable or real property. He cannot judge in actions which are declaratory of rights, or which are of a rescissory nature—for the purpose of nullifying deeds or legal proceedings. In other respects his jurisdiction extends to all actions on debt or obligation, without any limit as to the importance of the interests involved. He has also the same bankruptcy jurisdiction as the Court of Session. He does not act by a jury, though it appears that such an institution was formerly connected with the civil jurisdiction of the sheriff. He has authority by special statute summarily to decide small debt cases, that is, cases where the pecuniary value of the matter at issue does not exceed 12*l*. By railway statutes and other acts of local administration special functions are frequently conferred on him, and in the clauses for taking lands he is usually appointed to act as presiding judge when a jury is appointed to be empannelled. The decisions of the sheriff, when no proceedings have been taken to enforce them, may be carried into the Court of Session by advocation.

The authority of the sheriff in matters criminal is practically to a great extent measured by the proceedings of the crown lawyers in leaving prosecutions to proceed before his court, or removing them to the Court of Justiciary. It is not very clearly to be traced how far, in old practice, the sheriff's jurisdiction was inferior to that of the Court of Justiciary: he had undoubtedly the power of punishing with death, though it has been long disused. The power of transporting, which is of comparatively late introduction, he never possessed, not having any criminal authority beyond his county. By degrees it came to be considered that the jurisdiction in the four pleas of the crown—murder, rape, robbery and wilful fire-raising—was exclusively in the higher court. Important criminal cases in the sheriff court are tried by jury. In more trifling matters the sheriff performs the functions of a police magistrate. In these cases the punishment must not exceed a fine of 10*l*. or sixty days' imprisonment (9 Geo. IV. c. 29).

SHEW-BREAD (לֶחֶם פָּנִים), *lechem-panim*, "bread of faces," or, as it has been rendered, "presence bread," was the name given to the twelve unleavened loaves of bread, one for each of the tribes of Israel, which were constantly displayed on a golden table in the holy place of the Tabernacle and Temple. They were made of the finest wheat flour, and laid on the table in two similar piles, with frankincense and salt put over them. Every Sabbath they were renewed, and the old loaves were eaten by the priests in the holy place. The frankincense which was placed upon the shew-bread constituted it one of the "offerings made by fire to the Lord." The golden table on which they were placed was called the table of shew-bread. Wine was also placed upon it, and it was furnished with gold dishes, bowls, and spoons. None but the priests were permitted to eat of this bread; yet David, when in great need, ate of it, and incurred no blame.

SHIELD was a part of the ancient armour designed to ward off the strokes of the sword and all kinds of missiles. Shields were borne on the left arm, and were of different forms and sizes, and they were accordingly designated by different names. The large circular or oval shield, the invention of which was ascribed to Prœtus and Acrisius of Argos, was called in Latin *clypeus*, and in Greek *aspis* or *sacos* (ἀσπὶς or σάκος). A smaller kind of round shield was called *parma;* and a smaller kind of oval shield was called *pelta*. *Scutum* was properly speaking a square or oblong shield. The ancient writers, however, do not always accurately distinguish these different shields, but apply the name which properly denotes a particular kind of shield to shields in general. The shields in the earliest times were made of osiers twisted together (γέῤῥα), or of wood, and this framework was covered with the skins of oxen, of which there were mostly several layers, one over the other, whence Homer frequently calls the shield "seven-hided" (ἑπταβόειος). Xenophon ('Anab.,' i. 8) describes the Egyptians, even of his time, as using wooden shields. The whole rim was surrounded with a metal edge. In the centre of the outer or convex side there was a projection called the *ómphalos* (ὀμφάλος), or *umbo*, in which sometimes a spike was placed, which served as a weapon of attack against an enemy who approached too near. The object of the umbo, however, was to make the missiles glance off from the shield. In the inner or concave side there was a band of metal or leather, which went from rim to rim as a diameter, and under which the arm of the soldier was placed, so that the shield hung on the arm. Around the inner edge there was a number of small thongs, by means of which the shield was managed with the hand. The shields of distinguished persons, even as early as the time of Homer, were covered with metal plates, and frequently adorned with embossed figures. These figures were often of exquisite workmanship, as may be inferred from the descriptions of the magnificent shields of Achilles and Hercules in Homer and Hesiod. The shields of horsemen were generally smaller than those of the foot soldiers. The use of shields continued from ancient times throughout the middle ages, until they were made useless by the introduction of fire-arms.

The shields of individuals, as well as of whole divisions of an army, had sometimes particular devices relating to memorable events in their history, and these are generally supposed to be the first traces of the armorial bearings of more modern times. The numerous specimens of shields show that the knights of the middle ages were no less fond of adorning them with embossed figures, precious stones, &c., than the ancients. [ARMOUR.]

SHIFTING USES. [USES.]

SHIITES is the name of a sect among the Mohammedans. The word comes from *shiah*, "a faction, party, or set of men who separate themselves from the rest of the community," and who entertain religious opinions contrary to those of the *Sunnites*, or people who belong to any of the four orthodox sects of Mohammedanism. The name of *Shiites* is principally used to designate the sectaries or adherents of Ali Ibn Abi Tálib, who maintain him to be the lawful khalif and imám, and that supreme authority, both in spiritual and temporal matters, belongs to his descendants.

The Shiites are divided into numerous sects, of which the principal are: the *Imámians*, or those who believe that the office of imám, or head of the church, is not dependent on the will of the people, and that religion consists solely in knowing who is the true imám; the *Zeydians*, so called from the name of their founder, Zeyd, son of Ali, surnamed Zeynu-l-abadin (the ornament of the servants of God); the *Khattabians*, or disciples of Abú-l-Khattáb, who maintain that paradise is no other thing than the pleasures of this world, which God grants to those with whom he is pleased: hence their indulgence in wine, music, and other things forbidden by the prophet. The Persians are Shiites, and the Turks Sunnites: hence the cause of the schism still subsisting between them, which has been maintained on both sides with ardent zeal and implacable hatred. The chief points wherein they differ may be reduced to three:—1. The Shiites reject Abú Bekr, Omar, and Othmán, the first three khalifs, as usurpers and intruders; whereas the Sunnites respect them as rightful imáms. 2. The Shiites prefer Ali to Mohammed, or at least look upon him as his equal in every respect; whilst the Sunnites admit neither Ali nor even any of the prophets to be equal to Mohammed. 3. The Sunnites receive the *Sunna*, or body of traditions concerning the prophet, as of canonical authority; the Shiites reject it as apocryphal and unworthy of credit.

SHIP. The ships of war employed at first by the maritime nations of modern Europe were galleys, moved either by wind or oars, and were similar, probably, to those of the Greeks and Romans. In the beginning of the 15th century, vessels of a like kind, but of greater dimensions, constituted portions of the navies of France and Spain; they were called Carraques, and it is said by a French author of that age that the English ships scarcely dared to approach them. The term Galeasse was afterwards applied to a kind of war galley which was of greater length in proportion to its breadth than those generally constructed; its rowers were covered by a narrow deck running along each side of the vessel, and on this small cannon were mounted. Such were the vessels used by the Venetians at the battle of Lepanto.

Before the reign of Henry VII. the naval force of this country consisted only of the vessels furnished at short notices by the Cinque-ports, besides such as were hired from English or foreign merchants; and, according to Du Bellay, some of the ships were a sort of long galleys called Ramberges, in the management of which the English mariners are said to have been very expert. Henry VII. caused to be constructed the Great Harry, the first ship which can be ranked as one belonging to the royal navy of England; and his successor, in 1515, in emulation of Francis I., who had built a ship called the Caracon, carrying 100 guns, caused one of equal burden (about 1000 tons), and carrying 122 guns, to be constructed. This was called the Henry Grace de Dieu. It appears to have been built rather for magnificence than use; not more than 13 of the guns were 9-pounders or upwards; and its construction must have been very defective, for it is said to have steered badly and to have rolled incessantly. After having made one voyage, it was disarmed at Bristol and suffered to decay. The French ship was equally unfortunate, having been accidentally destroyed by fire at Hâvre. Henry VIII. exerted himself, however, to place the maritime force of the nation in a train for being improved, for which purpose he organised the Admiralty and Navy Boards, and formed dockyards at Deptford, Woolwich, and Portsmouth. [NAVY, BRITISH.]

During the reigns of Edward VI. and Elizabeth the royal navy became very powerful, and at the death of the queen it consisted of 42 ships of war. In the time of James I. was built (1610) a ship called the Prince, carrying 64 guns, and of 1400 tons burden, being the largest which had been till then constructed. And before the civil war broke out, Charles I. caused to be built one called the Sovereign of the Seas, which carried above 106 guns, small and great; her length was 128 feet, and her breadth 48 feet.

The ships of that age, foreign as well as English, were constructed with hulls extravagantly high, while the lower guns were frequently not more than three feet above the water; they were consequently very liable to ship seas at the lower ports during an action, when the waves ran high, or the ship heeled considerably. But the rivalry between England and the United Provinces in the 17th century, and the desire which Louis XIV. entertained to raise the navy of France to an equality with those of his neighbours, led to the construction of ships capable of carrying artillery of much greater calibre than had before been used at sea. The French king actually caused to be built at Toulon a ship called the Royal Louis, which carried 12-, 24-, and 48-pounders on its upper, middle, and lower decks respectively. In the same age, and during the 18th century, naval architecture was zealously studied in France; and the English constructors were so sensible of their inferiority, that in most of the ships built in England at that time the proportions were copied from those of ships which had been taken in action from the rival nation. Thus the Leviathan was built at Chatham nearly in conformity to the Courageux, a French 74-gun ship; and several others according to the construction of the Invincible, which had been taken by Lord Anson during the Seven Years' War.

During the 17th century the custom continued of giving to the sterns a great elevation above the surface of the water, and of loading that part, as well as the bows, with ornaments. The sterns of ships of war were, till about forty-five years since, made, at their junctions with the sides, of an angular form, or, as they were called, square; and before 1729 they had projecting galleries or balconies extending across them, and to some distance along each after-quarter of the ship. The galleries were afterwards much diminished in breadth; but it was not till 1796 that, by the influence of Lord Spencer, who was then the first lord of the Admiralty, these, as well as the great projecting heads, were entirely omitted in the construction of ships. In 1816 Sir Robert Seppings' proposed to make the sterns curvilinear like the bows, but more flat; and by the adoption of his plan there was gained considerable strength, such a form enabling the ship to resist with great effect the force of a sea in striking the stern, and that of shot when fired against it. With respect also to the means of defence at the stern and quarters of a ship, it may be observed that the curvilinear stern has greatly the advantage over those of an angular construction, there being in the angular an interval opposite each quarter of the ship towards which none of the after-guns can be brought to bear, while such interval does not exist in the curvilinear. In a ship with a curvilinear stern, the ports may be disposed so as to allow guns to fire in any direction diverging from a centre within the ship; and at the same time the after broadside guns may be trained so as to fire obliquely towards the fore or after part of the ship. Thus there will be afforded several intervals opposite the stern and quarters, within which the lines of fire may cross each other; and consequently the defence will be as powerful about the stern as at any other part of the ship. It may be added that when the guns in a square stern are trained at their greatest degree of obliquity to the sides of the ships, their muzzles will be considerably within the timbers; and consequently, in firing, some danger may exist of blowing away part of the stern or quarter. The curvilinear form is now, with slight modifications, generally adopted for ships of war; and the only objection hitherto made to it is that the interior accommodations are thereby rather diminished.

In 1791 there was formed, in London, a Society for the Improvement of Naval Architecture; and its first steps consisted in offering prizes for the best papers which should be written on the subject of the resistance of fluids, on designs for vessels, on the proportions of masts, &c. The association threw much light on the art of constructing ships; and both the theory and practice of that art have been advanced by means of the school which was attached to the Naval College at Portsmouth, under the superintendence of Dr. Inman. During the year 1860, however, an Institute of Naval Architects, under the presidency of Sir John Pakington, was originated in London, and bids fair to bring together the ablest members of the profession in England, as also men eminent in mechanical science. The late principal of the School of Naval Architecture, the Rev. Dr. Woolley, has already given a useful paper on mathematical theory, while men like Maudslay, Scott Russell, Grantham, Fairbairn, &c. have contributed valuable assistance. ('Transactions of the Institute of Naval Architects for 1860.')

In the present article it is intended to give some account of the mathematical principles of naval architecture; the mechanical construction of ships being reserved for the articles SHIP-BUILDING and STEAM VESSEL.

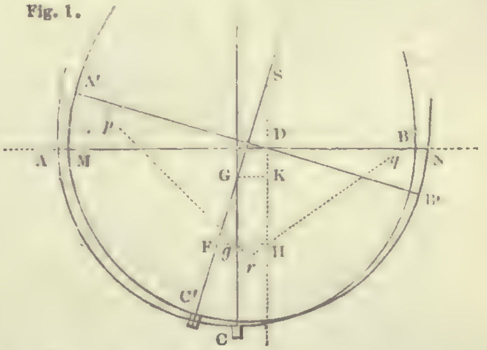
The body of a ship about its middle has nearly the form of a portion of a hollow cylinder, with its axis horizontal, and its convex surface downwards. Above the surface of the water on which it floats the sides are curved, so as at the head to have, in a horizontal direction, the form of a Gothic arch more or less acute. The breadth diminishes gradually towards the stern, which above water is either a plane surface nearly perpendicular to the ship's length, or, agreeably to the construction introduced by Sir Robert Seppings, curved so as to have, in a horizontal section, nearly the form of a semi-ellipse. Below the surface of the water the body of the ship is curved in a horizontal direction towards the head and stern, so as to terminate at those places in angles which diminish from that surface downwards; and thus a vertical section, taken perpendicularly to the length of the ship, at some distance from the middle towards either extremity, presents on each side the form of a curve of contrary flexure.

Experiments have shown, that when the quantity of sail is the same, the velocity of a ship is increased by increasing the ratio between its length and breadth, and both English and French constructors have gone on for many years augmenting that ratio; but this increase has its limit. The advantage of diminished breadth is accompanied by a diminution of stability, and a deficiency in this respect may produce serious evils. It may prevent the use of the lower guns on the lee-side from the fear that the ports may be under water, and the use of the guns on the weather-side from inability to give them sufficient depression; and by causing the keel to take an oblique position in the direction of its depth, the lateral resistance of the water being diminished, the lee-way of the ship is increased. The power of the rudder and sails to produce rotation about a vertical axis is greater in a long than in a short ship, because the rudder and sails are at greater distances from that axis, and because the impulse of the water on the rudder is more direct: yet the resistance which the water opposes to that rotation increases in a still higher ratio; and thus the difficulty of working to windward is increased with the length of the ship. Lastly, the quantity of artillery in a ship will indirectly affect the relation between the length and breadth; for an increase of weight above water produces a diminution of stability by causing the centre of gravity of the ship to be more elevated, and this evil must be counteracted by increasing the breadth. In several English ships of war carrying from 46 to 120 guns, it has been found by admeasurement that the ratio of the breadth to the length varied from $\frac{1}{3{\cdot}93}$ to $\frac{1}{3{\cdot}61}$, and that it had no dependence either upon the number of guns or upon the tonnage of the ship. The greatest length which may be given to ships of war is a point still undetermined; and the length seems to have hitherto gone on increasing in the navies of all nations. In 1786 was built the Victory, of 100 guns; this was then the greatest three-decker in the British service, and its length was 186 feet. In 1793 the Ville de Paris, of 110 guns, and 190 feet long, was built at Chatham; and in 1809 was built the Caledonia, of 120 guns, whose length was 205 feet, while the Hood of 91 guns and 3232 tons, launched, at Chatham, in 1859, is 238 feet long, and the Galatea frigate, launched in 1859, having 26 guns, and being of the burden of 3202 tons, has a length of 280 feet.

In the Vernon, and other ships which were built according to the designs of the late Sir William Symonds, the form of a transverse section passing vertically through the hull differs from that which had been before given to ships, in exhibiting an increase of breadth above the plane of floatation (a horizontal plane passing through the ship when she floats upright, and coinciding with the surface of the water). This construction produces, without any diminution of velocity, an increase of stability not only when the ship is afloat, but also when, on lying aground, she is subject to the force of waves against her side. It may however be said to be attended by the disadvantages of too great stability; that is, it may cause the ship to be considerably strained, and the masts to be carried away by a sudden impulse of the wind.

The lateral action of the wind against the sails, and of the waves of the sea against the hull of a ship, are the causes that the plane passing through its masts is made to decline from the vertical position which it has when the ship is at rest; and the ship is then prevented from being overturned only by the reaction of the water against the bottom and sides. The momentum of this reaction is that which is called the stability of the ship. The axis of the rotation has been placed by different writers in different situations, but both Bouguer and Euler have proved that, if the ship has not at the same time a pitching motion, it should be considered as a horizontal line passing through the centre of gravity of the ship. In order to find approximatively the dependence of a ship's stability on its length and breadth, let it be supposed that the ship is a homogeneous solid in the form of a prism or segment of a cylinder having its axis in a horizontal position; and, the vessel being supposed to float upright, let A B C (*fig.* 1) be a transverse section through the immersed part in a vertical plane passing through G and g, which are respectively the centres of gravity of the whole solid and of that part (A B) coinciding with the surface of the water: let also A′ B′ C′ be the position of the same section when the vessel is inclined. Now, while the weight of the ship remains the same, the volume of the immersed part is the same whether the ship be upright or inclined, and the volume raised above the water by the inclination on one side is equal to the volume depressed below it on the other; therefore the area M C′ N may be considered as equal to A C B, and A′ D M to B′ D N. Next let p and q be the centres of gravity of the trilateral spaces last mentioned; then, by mechanics, the centre of gravity of M D B′ C′ will be at some point, as r in $p\,g$ produced, the displacement of g by the inclination being supposed to be very small; and the centre of gravity of M C′ N (the section immersed when the solid is inclined) will be at some point H in $q\,r$: also—

Fig. 1.



$$\mathrm{A'B'C'} : \mathrm{A'DM} : : pr : gr, \text{ and}$$

$$\mathrm{MC'N}\ (=\mathrm{A'B'C'}) : \mathrm{B'DN}\ (=\mathrm{A'DM}) : : gr : r\mathrm{H}.$$

Therefore, $p\,r$ and $q\,r$ are cut proportionally in g and H; and g H is parallel to $p\,q$. Consequently—

$$pr : gr : : pq : g\mathrm{H},$$

$$\text{or } \mathrm{ABC} : \mathrm{A'DM} : : pq : g\mathrm{H};$$

and if the inclination of the ship is very small, g H may be considered as parallel to A B. Draw the vertical line H S, and G K parallel to A B; then $g\mathrm{H} = \mathrm{GK}$.

The area A B C may represent the volume (V) of the displacement, or of the immersed part of the ship; and the area A′ D M, the volume raised above or depressed below A D in consequence of the inclination. This trilinear space being supposed to be very small, it may be considered as a triangle right-angled at M: and if the length and half-breadth of the solid be represented by l and b respectively, we have $\frac{1}{2}\mathrm{A'M}.l.b$ for the representation of the elevated or depressed volume. But A′M varies with b; therefore, such volume varies with $l.b^2$. Again, by mechanics, the distance of the centre of gravity of each of those volumes from a horizontal line passing through D, in a direction parallel to the axis of the solid, is equal to $\frac{2}{3}b$; therefore, the line $pq = \frac{4}{3}b$, or pq varies with b. Then substituting, in the last proportion above, V for A B C, $l.b^2$ for A′DM, and b for pq; also putting G K for g H, we find that G K varies with $\frac{l.b^3}{\mathrm{V}}$; or $\mathrm{V.GK} \propto l.b^3$. Now the force of the water to prevent the ship from being overturned taking place, by hydrostatics, in the vertical line H S passing through H, and being represented by V; also the ship being supposed to turn about a longitudinal axis passing through G, we have V.G K for the momentum of the ship's stability; but the triangle GKS is similar to A'MD, all the sides of one being perpendicular to those of the other: therefore

A'M : DM : : GK : GS.

Again, A'M varies with DM; therefore, GK varies with GS and V.GS ∝ $l.b^3$: that is V.GS expresses also the momentum of the ship's stability. The point S is called the meta-centre, and it indicates the most elevated position which the centre of gravity G can have consistently with the stability; for when G coincides with S, it is evident that the above expression vanishes.

Since the depth of the ship does not enter into the expression $l.b^3$, it may be inferred that when ships have equal lengths and breadths, they will have equal stabilities, whatever be their depths. Again, when they have equal breadths, their stabilities will vary with their lengths; and when they have equal lengths, the stabilities vary with the cubes of their breadths. It follows also that, in general, the stability of a ship is directly proportional to its length and to the cube of its breadth, whatever be its depth.

In the next place, in order to find approximatively the relations between the velocity of a ship and its dimensions, let the ship be represented by an isosceles triangular prism having the greatest rectangular surface uppermost and parallel to the surface of the water, and the triangular ends perpendicular to that surface, so that the fore and after parts are rectangular planes inclined to the same surface; then for the present purpose we may assume that the resistance experienced in moving through the water is expressed by $v.^2 \text{A} \sin^3 \text{I}$. [HYDRODYNAMICS], where v is the velocity of the vessel, A the superficies of the inclined front, and I its inclination to the surface of the water. But the resistance of the water is directly proportional to the moving power, that is, to the pressure of the wind on the sails, and this last varies with the area of the sails, which may be represented by a: therefore, $v^2 \propto \frac{a}{\text{A}.\sin.^3 \text{I}}$. Again, the momentum of the ship's stability is directly proportional to the momentum of the wind on the sails, and the latter is expressed by the product of the area of the sails into the height of the centre of pressure (centre of gravity of the sails) above the axis of rotation: now this height varies with the height of the sails; that is, with the square root of their area, the sails in different ships being supposed to be similar plane figures. Therefore, the momentum of stability varies with $a^{\frac{3}{2}}$, or $a \propto$ (moment. of stability)$^{\frac{2}{3}}$. Let l be the half length of the vessel, b its breadth, and d its depth; then the momentum of stability as above may be represented by $l.b^3$, A will be equal to $b(l^2+d^2)^{\frac{1}{2}}$ and $\sin^3 \text{I}$ to $\frac{d^3}{(l^2+d^2)^{\frac{3}{2}}}$. Hence, $v^2 \propto \frac{l.^{\frac{2}{3}} b(l^2+d^2)}{d^3}$; and this being simplified, neglecting $l^{\frac{2}{3}}$, which may be considered as small when compared with $l^{\frac{8}{3}}$, we have $v \propto \frac{b^{\frac{1}{2}} l^{\frac{4}{3}}}{d^{\frac{3}{2}}}$.

This expression indicates that the velocity will be increased by diminishing d, which may represent the ship's draught, or the depth to which she is immersed. It is evident also that the like effect will take place if the length or the breadth, or both, are increased (the breadth of the sail being supposed to increase with that of the ship); and since, in this case, the stability will at the same time be increased, this will permit the ship to carry a greater quantity of sail; but the number of the crew being supposed to vary with the area of the sail, an increase of the latter is in general attended with a corresponding increase of expense. The factors in the value of v being different powers of b, l, and d, it thence follows that ships having the same proportions possess unequal sailing properties; it may be perceived indeed that a small ship built according to the proportions of a large one which is known to sail well will not possess the like good quality. On the other hand it may be inferred that a vessel having the same proportions as a good one of smaller dimensions will be superior to the latter. If two ships carry sails proportional to their stabilities, and if the height of the lower tier of guns above water be the same in both when the ships float upright; then, the inclinations of the planes of their masts being also supposed to be equal, the lower guns of the smaller ship will be farther from the water than those of the larger ship, and, in action, the latter might be in danger when the other would be safe. Consequently, if the greatest possible quantity of sail be given to the smaller ship, a smaller quantity relatively to its stability ought to be given to the larger.

The discovery of the elements on which depend the stability and the sailing properties of ships will probably be made rather by studying the proportions of such as from experience have been found to possess the desired qualities, than by purely scientific researches; and as a step preparatory to this study it will be necessary to be acquainted with the methods by which, in a body like a ship, which cannot be considered as corresponding to any geometrical solid, the areas of sections, the volume of the whole or of the part immersed in the water, the position of the centre of gravity of the hull or the sails, &c., are found.

The method of equidistant ordinates is generally used for these purposes; and in finding the area of a section, some line in it being taken as an axis, an uneven number of lines as ordinates are drawn or supposed to be drawn at equal distances from one another perpendicularly to that line till they meet the surface of the ship. The lengths of these ordinates being known by actual admeasurement, or by the scale of the drawing, and also the distance between them; and the curve line in which the plane of the section meets the surface of the ship being considered, between every three consecutive ordinates, as an arc of the common parabola; by Sterling's rules, the area will be found as follows: let the figure represent the half plan, divide it into any number of equal parts, say eight.

Fig. 2.

Then area $= \frac{r}{3}(\text{A}+4\text{P}+2\text{Q}) = \frac{2r}{3}\left(\frac{\text{A}}{2}+2\text{P}+\text{Q}\right)$ in which

A = sum of first and last ordinates,
P = sum of even ordinates,
Q = sum of remaining ordinates,
r = common distance between the ordinates;

or, according to his second rule, the ordinates may be drawn so that the equal intervals are made some multiple of the number 3, in which case the

$$\text{Area} = \frac{3r}{8}(\text{A}+2\text{P}+3\text{Q}) = \frac{3r}{4}\left(\frac{\text{A}}{2}+\text{P}+1\tfrac{1}{2}\text{Q}\right) \text{ where}$$

A = sum of first and last ordinates,
P = sum of 4th, 7th, 10th, &c., ordinates,
Q = sum of remaining ordinates,
r = common distance.

Either rule may be used, for whether the curve be considered as a common parabola, or as a cubic parabola, will scarcely affect the practical result.

By either of these rules the area of a vertical section through the middle of the ship's breadth in a longitudinal direction, or through any part of the ship's length in a transverse direction, and also the area of a horizontal section coincident with or parallel to the surface of the water, may be found. The same formulæ may be applied to determine the volume of the whole hull, or of the displacement; for this purpose vertical sections may be supposed to pass through the equidistant ordinates drawn perpendicularly to the longitudinal axis of the ship, and their areas to be computed as above. The formulæ may also be employed to determine the momentum of any part of the ship with respect to some line about which it may be made to turn, or with respect to a plane passing through such line.

In order to find the centre of gravity of the displacement, that is, of the immersed part of the ship (considered as a homogeneous solid) when the ship floats upright; imagine that immersed part to be divided by equidistant vertical planes perpendicular to the ship's length, and also by equidistant horizontal planes; then the area of each horizontal section between every two vertical planes being multiplied by the vertical distance of that horizontal section below the surface of the water, and all the products being added together by either of the above formulæ, the sum will be the momentum of the immersed part with respect to the horizontal plane at the surface of the water. This momentum being divided by the volume of the immersed part computed as above, gives by mechanics the distance of the centre of gravity below the surface of the water. In a similar manner may be found the position of the centre of gravity with respect to a vertical plane passing perpendicularly to the length of the ship, suppose at one of its extremities; and thus its position may be completely determined. From the symmetry of the ship's figure on each side of a plane passing through its masts and keel, the centre of gravity of the whole ship will always be in that plane; and that of the immersed part will be in the same plane when the ship floats upright.

The position of a vertical line passing through the centre of gravity of the whole ship may be found by determining that of a vertical line passing through the centre of gravity of the displacement; for, by hydrostatics, when the ship floats with its masts upright, these lines are coincident. But the determination of the place of the centre of gravity in this line is a problem of considerable difficulty on account of the complexity of the subject, arising from the form of the hull, the positions of the masts, rigging, guns, lading, &c.: and it can only be found mathematically by ascertaining the place of the centre of gravity and the weight of every separate object constituting the mass of the ship and its lading. The momenta of all these objects being computed with respect to any one plane, as that of floatation (the horizontal plane at the level of the water), the difference between the sums of the momenta of the objects above and below that plane is, by the nature of the centre of gravity, equal to the product of the weight of the whole ship into the distance of the required centre of gravity from the same plane. Hence the situation of this point might be found.

The most simple mechanical method of finding the centre of gravity of a ship is probably that which was proposed by Mr. Major in the 'Annals of Philosophy,' June, 1826. It consists in making the ship when afloat heel (the plane of its masts to incline) through equal angles by means of weights applied successively to a mast, and made to act horizontally at different distances above the deck; these weights being reduced to directions perpendicular to the inclining mast (by multiplying them into the cosine of the inclination), and then multiplied into their respective distances from the unknown centre of gravity of the ship, will give two products which are equal to one another; each of them being equal to the momentum of the resistance by which the water tends to prevent heeling; hence by algebra the distance of the centre of gravity from either of the points at which the weights are applied may be found.

In the expression for the momentum arising from the pressure of the wind against the sails, it is usual to consider the whole force of the wind as acting at the centre of gravity of the sails; and this point may be found by multiplying separately the area of each sail into the distance of its centre of gravity above a horizontal axis passing through the centre of gravity of the ship. The quotient arising from the sum of these momenta divided by the sum of the areas of all the sails will give the distance of the required centre of gravity above that axis; and similarly the position of the centre of gravity of the sails with respect to any vertical line as an axis may be obtained.

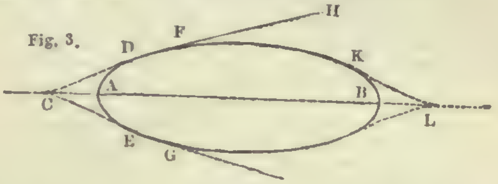
To find the centre of gravity of the displacement, or of the immersed part of the ship supposed to be homogeneous, when the plane of a ship's masts is made to incline by the lateral action of the wind, the axis of rotation being supposed to be a horizontal line passing through the centre of gravity of the whole ship, there must be first obtained by trial the position of a horizontal line in which the plane of the surface of the water will cut the body of the ship when in the upright and inclined positions respectively, so that the volume of the part raised above the water in consequence of the inclination may be equal to that of the part depressed. Let a line passing through D, *fig.* 1, perpendicularly to the paper, be that horizontal line; then the sum of the momenta of the elevated and depressed volumes may be found by computing the areas of the trilineal figures A′DM, B′DN, in all the vertical sections taken at equal distances from one another in the direction of the ship's length, multiplying them separately by the distances of their centres of gravity from a vertical plane passing through the same horizontal line, and then adding all the products together by one of the formulæ above given. In the 'Quarterly Journal of Science,' April, 1830, the area of either triangle, as A′DM, is expressed by $\frac{\gamma+\gamma''}{2}\gamma' \sin\frac{1}{2}\theta$, where $\gamma =$ DM, $\gamma'' =$ DA′, $\gamma' =$ a line drawn from D to A′M, bisecting the angle A′DM, or θ (the angle of heeling). Also the momentum of the same triangle with respect to the point D is expressed approximatively, and supposing the angle of heeling to be 7° (the greatest at which a ship of war can use her windward guns), by $.0203\gamma\gamma''(\gamma+\gamma'')$.

In order to find an expression for the stability of a ship, let G be its centre of gravity, and when the ship floats upright let g be the centre of gravity of the immersed part supposed to be homogeneous. Now when the plane of the masts is inclined, g will be situated at F, and in that case let H be the place of the centre of gravity last mentioned; then by mechanics, FH will be equal to the quotient arising from the division of the sum of the momenta of the elevated and depressed volumes by the volume of the immersed part of the ship. But if θ be the angle of inclination, we shall have Fg = GF sin θ; therefore gH or GK may be found. This being multiplied by the weight of the ship and its burden (= the force of the reaction of the water in the direction HS), gives the expression for the stability.

The plane of a ship's masts is made to decline from a vertical position not only by the action of the wind against the sails when the direction of the wind does not coincide with that plane, but also by a wave striking the ship in a direction oblique to the horizon and to the plane of the masts; and in both cases the variations in the force by which the inclination is produced and the re-action by which the water tends to bring back the plane of the masts to a vertical position cause the ship to roll about some longitudinal axis, which is supposed to pass horizontally through the centre of gravity of the whole ship. Now, if a horizontal plane coincident with the plane of floatation pass through AB when the ship floats upright, and G, the centre of gravity of the ship, be below that plane, as in *fig.* 1; in order to preserve the equality of the immersed volume when the ship is inclined, the plane which passed through AB must take such a position as A′B′. This will cause G to ascend; that is, the ship will rise on the water. On the other hand, if G had been above AB when the ship was upright, the latter would descend on the water when it is made to take an inclined position. Such rising or descending is a cause of the ship being shook or strained in rolling; and this evil can be avoided only by having the centre of gravity, G, coincident with the plane of floatation. It is necessary to observe, on the other hand, that by keeping that centre higher, or bringing it nearer to the meta-centre S, the stability of the ship, which varies directly with the distance GS or GK, is proportionally diminished. The pitching of a ship, that is, the alternate elevation or depression of either extremity of the ship as the latter passes over a wave, is attended by a corresponding rising or descending of the whole ship; and the strain thus produced will evidently be so much the less as the centre of gravity is nearer the level of the plane of floatation and the middle of the ship's length. It should be stated here that, since a ship in tacking is supposed to turn horizontally about a vertical axis passing through its centre of gravity, the resistance then experienced, which is proportional to the square of the distances of its extremities from that axis, will be a minimum when the centre of gravity is in the middle of the ship's length; but, on the other hand, the power of the rudder depending on its distance from the same axis of rotation, that power would be increased by having the centre of gravity at some distance before the middle point.

When a vessel which is partly immersed in a fluid moves through that fluid, it always experiences a resistance in a direction contrary to that of its motion, in consequence of the inertia of the water; but it experiences also a resistance on account of the particles of water which are immediately struck by the vessel, and those immediately beyond them to a certain distance, being for a time compressed on all sides by the vessel and the surrounding fluid, and thus compelled to rise above the general level. The elevated fluid will be highest before the middle point at the bows of the vessel; and the hydrostatical pressure arising from the elevation, combined with the reaction of the neighbouring fluid, will cause the particles to flow off laterally in the direction of some curve-line whose convexity is towards the vessel, after which they will mix with the fluid on each side. Now let ADB, *fig.* 3, be a horizontal section through the ship at the general level of the water, and let CED be the space occupied by the confined water in front of the ship; then if an artificial prow of that acute form were given to the ship, the particles of water contiguous to the sides of such prow would create very little resistance in addition to that which arises from the inertia of the water, while the latter resistance will evidently be so much the greater as the bows are more obtuse. Beyond D and E the particles flowing along the side exert forces arising from friction, adhesion, and the lateral pressure of the neighbouring water; and at certain points, as F and G, they pass off in the directions of tangents at those points. The force of friction and adhesion is very considerable, particularly if the surface is rough and unequal; and if the vessel is moving with or against a current, the pressure against its sides is equal to that which would be experienced if the water were at rest, diminished or increased on any given area by the weight of a column of the fluid whose base is that area, and whose height is that which is due to the velocity of the water. It has been found moreover by experiment, that if both vessel and fluid are in motion, with equal velocities in the same direction, the buoyancy of the vessel is the same as if both were at rest; but when the velocity of the vessel is less or greater than that of the fluid in the same direction, the vessel either sinks or rises in the fluid by a quantity equal to the height due to the difference of the velocities, and this circumstance must in some measure modify the resistance of the water against the vessel.

Fig. 3.



Besides the resistance arising from the friction of the water along the sides of the vessel, there must be noticed the diminution of pressure against the after part, in consequence of the water displaced by the motion not falling in behind with sufficient velocity to bring the surface there to the same level as in front. The particles of water diverging from the sides of the vessel in oblique directions, as FH, are by the lateral resistance of the neighbouring fluid deflected so as to describe curve-lines which finally unite behind the stern in some point, as L. But the force exerted to deflect the particles from the direction FH causes a diminution of the pressure which the water would have otherwise exerted against the after part of the vessel; and consequently it is to be considered as an additional power opposing the forward movement of the vessel. The force of deflection, and consequently the retardation, will evidently be less in proportion as the tangent FH is nearer to the side of the vessel, or as the point F is more distant from the stern; and this circumstance indicates the advantage which ships of considerable length have over others. It is easy to understand however from the breaking and foaming of the water at the head and stern of a vessel when moving with considerable velocity, that the effects of the resistances will be greatly modified by the collisions of the particles of water with each other, and with the surface of the vessel, in consequence of the shocks produced by its motion, and by the effort of the water to return to a state of equilibrium.

In order to obtain an expression for the resistance of the water against a ship, the part of the immersed surface which is before the greatest transverse vertical section is supposed to be divided by a number of such transverse sections at equal distances from one another, measured perpendicularly between them, and by a number of sections parallel to the plane of floatation at equal distances from one another vertically. Thus the surface of the immersed part in front of the greatest transverse section is divided into trapezoidal figures; and a like division of the immersed part of the ship's surface abaft of the greatest transverse section is made. Each trapezoid, in an orthogonal projection of the fore and after part of the ship made on a plane parallel to the greatest transverse section, is then divided into two triangles by a diagonal line, and the area of each projected triangle (found by admeasurement of its sides on the scale of the drawing) is multiplied into the resolved force of the water upon it; that resolved force being expressed by the absolute force multiplied into the square of the sine of the inclination of the triangle on the ship's surface to the direction of the motion. The sum of the products is taken for the whole resistance of the water against the ship. In comparing the resistance against one ship with the resistance against another, it is evident that the absolute force of the water on each may be represented by unity.

Experiments sufficiently prove that the resistance experienced by a body in moving through a fluid is less when the greatest breadth of the body is at some distance before the middle of its length, than when it is precisely at that place, but the most advantageous situation of what is called the *midship section* (the greatest vertical section taken perpendicularly to the length of the ship) is far from having been as yet determined. In order to find its dependence upon the direct resistance of the water, M. Chapman proceeds in the following manner: He considers the ship to be represented by a solid in the form of two isosceles wedges joined together at their heads and to move in the water with the planes which are perpendicular to their edges parallel to its surface. Now it is evident that when the solid is at rest in still water, the opposite pressures of the water against the faces in front, and against those which are behind the plane of junction, or of the greatest transverse section, will be equal to one another in directions parallel to the length of the solid. Also that, when in motion, the front faces will experience directly that resistance of the water which is due to the velocity of the solid, and that the after faces, by receding from the water in consequence of the advance of the body, will lose a portion of the pressure which they would have experienced had the body been at rest, and which would thus have indirectly contributed to force the body forward. It must moreover be observed that the water is driven forward in front of the vessel with a velocity which may be represented by v'; and that as the water in front becomes higher than that which is behind the greatest transverse section, it will flow towards the stern with a velocity which may be represented by v''. Hence if A be the sum of the areas of the two oblique surfaces in front of that greatest section, and B that of the surfaces abaft of the same section; also if θ and θ' be the inclinations of those surfaces respectively to the line of motion, and v be the velocity of the body, we shall have, supposing the resistance to vary with the square of the velocity and the cube of the sine of the inclination,

$$\mathrm{A}\,(v-v')^2 \sin.^3\theta + \mathrm{B}\,(v+v'')^2 \sin.^3\theta'$$

for the value of the whole resistance; or, for A sin. θ and B sin. θ' putting their equal C (the area of the transverse section) the expression for the resistance becomes

$$\mathrm{C}\left\{(v-v')^2 \sin.^2\theta + (v+v'')^2 \sin.^3\theta'\right\}.$$

This formula indicates that such a body will always meet with less resistance when C is in front, than when it is abaft of the middle point in the length; that is, when θ is greater than θ': it indicates also that the place of the greatest breadth when the resistance is a minimum depends on the values of $v-v'$ and of $v+v''$, and that the greater v' and v'' are with respect to v, the farther should the greatest breadth be in front of the middle point.

Imagining a horizontal section through a ship at the surface of the water to present the form of four portions of parabolas, the two in front of the greatest transverse section being similar and equal on opposite sides of the longitudinal axis; and likewise the two portions abaft of that section being similar and equal to one another, but different from the two former portions, Chapman finds, as approximations to the place of that greatest section, that its distance in front of the middle of the ship's length may be four, six, or eight times the horizontal distance of the centre of gravity of the whole ship from that middle point. And his observation is that the first distance might serve for sharp vessels, as frigates, and the last for merchant ships, which are much broader than the others in proportion to their lengths. Colonel Beaufoy's experiments with solids of various forms indicate that, in general, the distance of the midship section in front of the middle point in the length should be one-tenth of the length.

It must be understood that the assumptions on which the formulæ expressing the relations between the principal dimensions of ships, and between the dimensions and velocity, have been investigated, are far from being conformable to the circumstances of a ship when moving through the water, and the same may be said of the above process for finding the place of the greatest transverse section; consequently, the formulæ afford but remote approximations to the rules which should guide the naval architect in the formation of a design. A far more perfect knowledge than we have at present of the action of the wind on the sails, of the resistance of the water, and of the conditions of stability in a ship, will be necessary before the results of analysis will be capable of being applied directly to the details of construction.

Having thus noticed the general mathematics involved in the question of producing the best form of floating body for propulsion along the surface of a fluid, and as adapted to the conveyance therein of heavy weights from place to place; the forms under which such bodies are usually constructed, either for purposes of war or commerce, demand our notice. The consideration of the mode of construction forms no part of the requisites of this article; we refer, therefore, to the general question of naval architecture, as illustrated under the words SHIPBUILDING and STEAM-VESSEL.

The most essential conditions in the construction of a ship are, that it be capable of carrying its stores and its artillery or lading; that it be moved by wind or steam with great velocity, and that it readily obey the motion of the rudder; that it have the necessary stability, so as not to be overturned when acted upon by the wind or waves; and, finally, that its rolling or pitching be attended with as little strain as possible on the timbers. These conditions are in some respects contrary to each other; and the degree of attainment for each will depend in part on the purpose, whether of war or commerce, for which the ship is built. The skill of the architect lies therefore in adopting such a construction as shall allow the quality most required to be obtained in the highest degree, without being attended by too great a sacrifice of the others. The form indicated above has by experience been found to afford the means of uniting the different conditions, as far as they are consistent with each other; but that form is capable of being varied within very distant limits. The subject of the resistance of fluids against bodies immersed in them is also so imperfectly known, that the most proper proportions which the several dimensions should have to each other, in order that such resistance may be as little as possible, are yet to be determined; and in the present state of science, those proportions can only be obtained from the dimensions of ships of different classes which have been observed to possess the best sailing properties.

In merchant ships an ample capacity is frequently of more importance than a great velocity in sailing; and in this case the relations between the length, breadth, and depth depend less upon hydrodynamical principles than the corresponding relations in ships of war. With respect to the latter, it is observed by Mr. Morgan, in his papers on naval architecture, that the number and weight of the guns constitute the basis of the design; for from these the weight of the whole ship, or the volume of the water which it will displace, may be estimated. The distance between the guns on the decks must be such as by experience has been found sufficient for working them; and hence the number of decks being given, the least length which the ship should have becomes known. The breadth also must in part be determined by the artillery; for on each side of the ship, between the hatches or ladder-ways and the rear of the gun-carriages after the recoil, there must be room for a free passage; but this element must also be great enough to afford the necessary stability, that the tendency of a lateral wind to turn the ship about a longitudinal axis may be resisted. The draught of water (the depth to which the ship is immersed) may depend on the depth of water in the harbours and roadsteads; but it should also be determined from experience, so that the ship may be prevented as much as possible from making leeway; and the height of the ship above water must be such that, while the upper tiers of guns are kept as low as possible, the height of the lowest tier above the water, when the ship floats upright, may be not less than six feet, in order that the lower guns may be worked when the ship has considerable inclination. Finally, the form of the body must be that which is most favourable for velocity, by causing the least possible resistance of the water at the bows and along the sides; which allows the greatest lateral resistance; and which will permit the rudder to act with most effect in causing the ship to be turned about a vertical axis. And if, when in the design for a ship all these conditions are fulfilled, the displacement (weight of the volume of water which would fill the space occupied by the ship below the general surface of the water in which she floats) is equal to the whole weight of the ship, the several dimensions may be considered as nearly correct.

With regard to ships of war, a reference to our word NAVY will show that so great are the changes resulting from the adoption of the screw as a means of auxiliary propulsion, that, together with a total revolution commenced in the system of armament, the discussion herein of embryo theories would be incompatible with our plan. Under the words GUN-BOAT, CLIPPER, &c., the subject has been already touched upon, but a few general remarks will be added under the heading STEAM-VESSEL.

Ships intended for the merchant service may be divided into three classes, as either "passenger carrying," "cargo vessels," or "passenger and cargo vessels." Among the first may be found perhaps some of the most beautiful models of steamers which the art of man, at this period, can produce. It is necessary, however, to concede that notions of beauty in a ship vary as our notions of their adaptation to certain purposes; for if we take speed alone as our standard of reference, slimness of form and lightness of rig appeal to the judgment, while the nautical connoisseur will, like the jockey among horses, detect at once among shipping the distinctive qualifications which stamp the racer, the charger, or, so to speak, the horse of burden.

Unfortunately, however, this *apparent* facility of rough appreciation forms one of the drawbacks to which naval architecture is liable. It is nevertheless capable of demonstration, that as in the horse an expectation of speed or otherwise is inferred by closer inspection, say of the length and freedom of the femur, so may the nautical eye scrutinise profitably various of the undermentioned qualifications of the ship. That a ship whose hull has been constructed according to the best rules of art does not always fulfil the conditions required, may depend on several causes. If the burden is placed too low, the rolling will be heavy, and the masts may be endangered; on the other hand, if the burden is too high, there may not be sufficient stability. With all the researches which have so lately been renewed, there seem to remain a few well recognised and established laws as to form which cannot be dispensed with in the construction of a perfect ship. It is by means of these that the unscientific builders of the country sometimes produce wonderfully good models. The following are the principal, namely :—

The bow should be sufficiently sharp to cleave the water with the least possible resistance :

Of sufficient fulness above load-water line to prevent too great plunging in bad weather :

Sufficiently free from unnecessary top-weight also to ease a ship in a sea way :

A bow in which the floor extends as far as possible into the forefoot, but blends easily into the general lines of the hull; serving as another check on inconvenient vertical motion.

The hull should have bearings or powers of floatation, so distributed as to sustain the internal weight without strain upon any particular part of the general frame of the vessel :

Should be so capacious as to admit of ample stowage, while its displacement at any depth presents a water-line free from too great curvature.

The floor should have such an arrangement of draft lines as to admit of both speed and stability, according to the work to be done by the vessel; for speed is well known to be influenced greatly by the fulness or otherwise of the midship section *at the bilge*, inasmuch as the shape of this part contributes largely towards the delivery or retardation of displaced water as it passes into the *run* of the ship past the stern-post : great proportionate length in a ship permits a fuller bilge line.

The stern should have the submerged part (called the *run*) as nearly wedge-shaped as possible in its water-lines, as viewed from above : the smaller the angle of the wedge the *cleaner* the run is said to be :

The lines of the run to spring from or blend with the lines of the hull without sudden change in the curve :

While so clean as to cause no dead water, yet to have the bearings above the light-water line so judiciously adjusted in the vertical sections as, from the capacity and gradual displacement of water at such times, to furnish an easy check to the violent motion of rolling or pitching :

So well arranged in its upperworks as to prevent unnecessary top-weight, while giving sufficient internal space for cabins and the requisite deck operations :

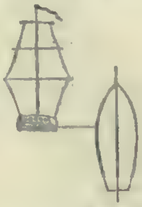
A proportion of length and breadth so nicely determined as not to give speed at the expense of stability, and *vice versâ* :

A forefoot so deep as to give what are called weatherly qualities, or to prevent the vessel, when close hauled, from being driven off the wind by every wave which meets the weather bow—while not so deep as to impede ready working in stays :

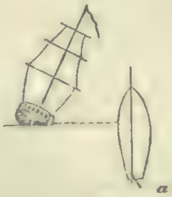
A heel so deep as to give sufficient power to the helm in its ample hold of the water, without increasing unnecessarily the draught of water.

It may well be imagined that the above requirements, so antagonistic in themselves, generate a vast variety of forms of vessels; but not even the absolute shape of the fabric itself can insure an accurate performance when under sail; for other important considerations arise even in the fitting and masting of the ship, as for instance :—

The masts should be so distributed in her length as to incline a little towards the stern (or should *rake*, as the phrase is); this has a double advantage: 1st, it tends to steadiness of the hull in a sea way, when moving upon her midship axis, in the action of pitching, inasmuch as the weight of the spars, sails, and rigging upon a raking mast has to be *raised* by the motion of the ship before the mast can be perpendicular; while in a perpendicular mast, such pitching motion is facilitated by any vertical disturbance of the water line, inasmuch as in this case the weight of the whole mast tends towards a lower point. 2nd, In a heavy gale the wind has less power on a raking mast when the ship is lying-to. And further, it has long been the practice to place the foremast of a line-of-battle ship very far forward, so far indeed as in some to plumb the forefoot. This has been supposed to be necessary from the general form of the hull, as a counteraction of too great an amount of weather helm when the ship heels, but it is scarcely questionable whether the new form of bow will not show the former disadvantage of placing the foremast, in some ships weighing perhaps thirty tons (including spars, sails, and gear), so far from the centre of gyration of the whole mass. It is no uncommon thing to see these old liners, when riding for instance at anchor in the Downs, pitching bows under, to the manifest danger of masts and everything. Another great defect of rig is mostly apparent in foreign vessels, wherein the lower masts are so long as to throw the centre of effort of their top-sails and top-gallant sails higher than necessary above the decks, and by thus increasing the leverage of the force of the wind, throwing the hull out of the perpendicular and distorting the water-line, as in the following diagram.



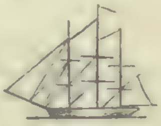
Water-line.



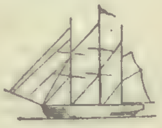
Water-line.

When such is the case, the vessel has a constant tendency to fly up to windward, and requires the helm to be so placed as to counteract this tendency, but it forms a complete drag upon her motion. (See *a* in the above figure.)

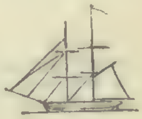
Enough has been said on the general consideration of a ship as a mere sailing body, as adapted to the propulsion of such bodies by steam. The subject will admit of further remark under the word STEAM-VESSEL. A few outline diagrams are here added in illustration of terms usually applied to the different descriptions of sailing vessels.



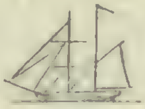
Ship.



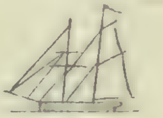
Barque.



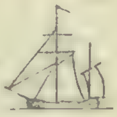
Brig.



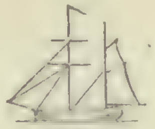
Brigantine.



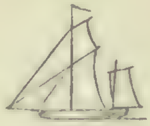
Schooner.



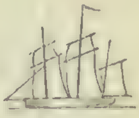
Galliot.



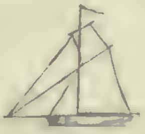
Ketch.



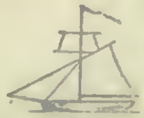
Yawl.



Lugger.



Cutter.



Sloop.

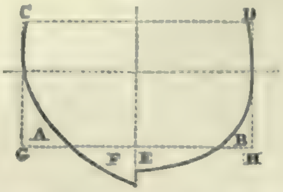
SHIPBUILDING, as a science, has, under the term Naval Architecture, become so extensive a subject as to render it difficult to condense within the limits of a concise statement, sufficient to illustrate even its main principles, without undue intrusion upon the consistent limits of a Cyclopædia.

The precise form of a ship need not here be a main consideration; under the word STEAM-VESSEL will be given such information hereupon as illustrates the question of speed; which, although belonging also to certain classes of sailing-vessels, is more immediately and more generally connected with steamers whose powers are dependent on a limited amount of their primary means of propulsion, namely, coal. We here only consider, under this word, the hull or body of a ship as a hollow shell, intended to accomplish a required displacement of water under different specific amounts of immersion. Were it merely the object to build such a fabric as is capable of floatation in a fluid at rest, the elucidation of principles already given would suffice; but we have to illustrate certain considerations which are conducive to *strength*: and a difficulty arises of fairly estimating the amount of strength demanded, not at any particular part in the frame of a ship, but throughout the whole mass; for it becomes a most intricate question to estimate in a ship even an approximate amount of *relative* strain, and its importance in the economical distribution of material may be said to comprise the most exacting demands on the skill of the accomplished mechanic and mathematician.

The subject here would evidently divide into two distinct branches; for while there exists in vessels of the mercantile marine a series of qualifications adapted to the general requirements of commerce, such as the carrying of heavy burdens, or of passengers, another class of ships is demanded of the naval architect which shall fulfil all the necessities of fighting ships; but those of the latter class will be more conveniently treated of under Steam-Vessel.

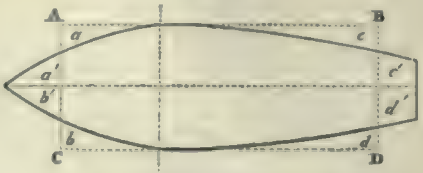
When a ship is to be constructed, the first consideration is the required amount of tonnage. This being once determined, a knowledge of the purpose for which the ship is intended regulates the builder in his fixing the amount of midship area, from which all the other dimensions originate. In forming the area of the midship section, the good qualities of the ship chiefly depend on the selection of the breadth (or beam as it is called) for on this rests the important question of stability or stiffness under sail. It is customary to consider the primary form of the ship as a quadrangular prism of contents equal to the required tonnage:—of course its midship section will be a rectangular parallelogram. Suppose, for example, it were required to build a ship of certain tonnage [Tonnage], whose midship sectional area is to be 805 square feet, and the beam 35 feet, then $\frac{805}{35} = 23$ feet the depth. The primary body plan and whole breadth plan would be as under:—

Fig. 1.



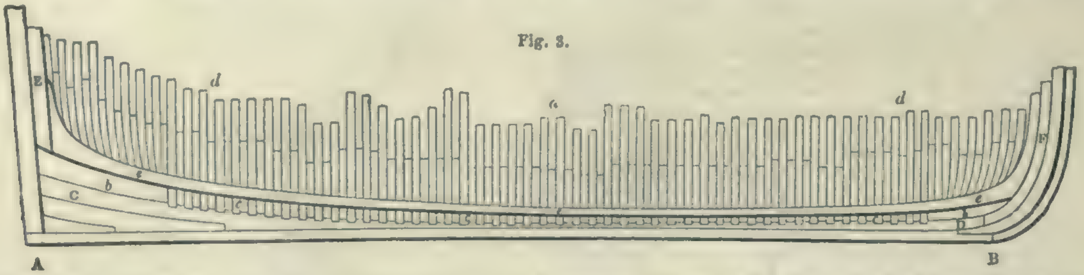
CGHD would be the midship area, CD the beam, CG the depth. Now although this represents the amount of displacement for tonnage, it requires the skill and taste of the naval architect to adapt the outline of such capacity to the requirements of the ship, having proper regard to speed, carrying qualifications, rolling, stability, &c. &c. This is to be done by an interchange of areas in the following manner:—Suppose a moderate amount of speed is to be blended with average carrying qualities, the dotted curve would be so drawn as to let the area E compensate for the abstracted area B; or if speed in particular be desirable, then the area F would compensate the area A. It will thus be manifest that a wide range of form is open to the shipbuilder, while his chief aim is not to disturb the amount of area of the midship section. And again taking the form of the ship at the load-water line—the primary parallelogram would be ABCD, a horizontal section of the primary quadrangular prism as under,—

Fig. 2.



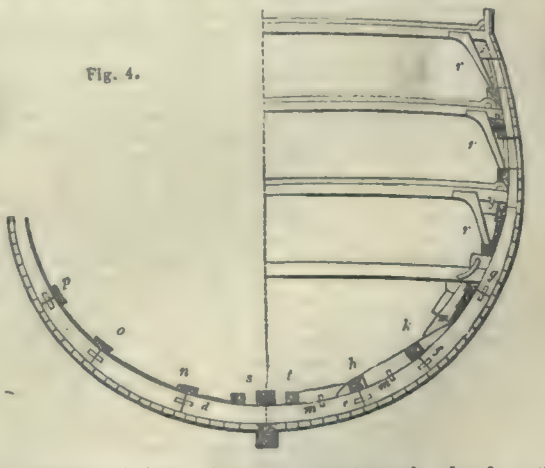
Now in order to shape the ends so as to give sailing qualities, it, as in the former case, again taxes the skill of the builder to interchange areas, so as not to disturb the gross displacement:—in the above figure we have supposed the area marked a to be taken from the parallelogram and transferred to a';—that marked c to be transferred to c':—b to b' and d to d'. Hence the outline in plan and section is determined, and drawings representing the necessary intermediate elevations and sections, generally on a scale of a quarter of an inch to a foot, are prepared, and copies of these, enlarged to the full size of the objects which they represent in the intended ship, are traced with chalk on the floor of an apartment called the "mould-loft." The length of the loft is generally equal to half that of the greatest ship which it may be proposed to build, and of the whole height of the hull in addition; so that there may be traced upon it a horizontal plan of half the ship in the direction of its length, and beyond one extremity of the plan a representation, in the same plane, of a transverse section of the ship in a vertical plane at the place of its greatest breadth. Such plan and section being laid down, there are drawn with chalk, from their proper places in the plan, representations of the timber ribs or frames as they would appear in as many transverse sections of the ship: pieces of plank about three-quarters of an inch thick are then cut so as to correspond to the forms of the timbers; and these, which are called the moulds, become the patterns by which the timbers are to be cut from the tree or log of wood. But, as such a mould can only give the form of the timber in the direction of its length, and as the oblique positions in which the timbers stand in the ship may cause the angle which the faces of each timber make with one another to be acute or obtuse, and to vary in the same piece, certain marks on the surfaces of the boards are used to indicate the directions in which the sides of the timbers are to be cut. The operation of cutting the timbers agreeably to the forms of the mould-boards is called "converting."

Fig. 3.



A row of blocks of oak are placed on the building-slip (ground cut in an inclined plane descending towards the water) in the direction of the length of the intended ship, so that their upper surfaces may be in a plane making an angle of about three degrees with the horizon; and on these blocks is laid the keel AB, *fig.* 3. This, which is the lowest timber of the ship, extends from one end to the other, and upon it is raised the whole fabric; it is of elm, and for a large ship it consists of two or more pieces scarfed together at their extremities. Timbers, called the "dead-wood," are then placed at C and D longitudinally upon the keel from each extremity of the latter towards its middle; the upper surface of this mass is cut in a curvilinear form *b*, *b*, and with this line the bottom of the ship's body is to coincide. At A and B, the extremities of the keel, the stern-post and stem-post are set up: the latter is curved near the bottom; and if the stern is to be what is called square, a particular frame, consisting of two transoms or horizontal timbers, and two side-pieces, is fixed above the stern-post, in order to determine the form which is to be given to this part of the ship. The sides and upper surface of the keel and dead-wood are cut to receive the floor-timbers (the lower portions, *d e*, *fig.* 4, of those timbers which are to form the ribs of the hull): these are placed across the keel perpendicularly to its length, and the other portions (called futtocks), *e f*, *f g*, &c., of which each rib is formed, are placed successively above them, abutting end to end, or the head of a lower one against the heel of that which is immediately above it. The ends of the futtock-pieces in every rib are made to fall near the middle of the length of those in the rib on each side of it; and they are united together by cylindrical coaks, or plugs of wood, which enter about two inches into those ends at the places of junction; *c*, *c*, *c*, &c., *fig.* 3, represent sections of the ribs made by a plane passing longitudinally through the middle of the keel, and the interior surfaces of parts of the ribs appear at *d*, *d*, &c. The ribs were formerly placed so that their planes were perpendicular to the keel, but Dr. Inman has disposed them so as to be in vertical positions when the ship floats upright. Except near the two extremities of the ship, their planes are perpendicular to a horizontal line drawn in the plane of floatation through the whole length; but at the bows always, and at the stern if the latter is to be curvilinear, the vertical planes with which the ribs on each side coincide are oblique to the length of the ship, in order

Fig. 4.



that, on a horizontal plane, the proper curvature of the extremities may be obtained. The rib-timbers above the surface of the water are nearly rectilinear, but below that plane they are made with various curvatures. About the middle of the ship they have at bottom nearly the form of a semicircle, while towards the head and stern they form curves of contrary flexure, uniting on the keel with their lower concavities towards the exterior of the ship.

It may be observed that the keel of a ship is not horizontal, or parallel to the plane of floatation when the ship is in still water, but is made lower towards the stern than it is forwards, in order to allow greater length to the rudder, and thus increase the power of the latter in giving a direction to the ship's motion.

The keelson, *e e*, *fig.* 3, is placed longitudinally above the floor-timbers, and immediately over the keel, and it is united to the latter by bolts which go through both, and through the floor-timbers: its transverse section is represented at *s*, *fig.* 4. In large ships two additional keelsons, *t*, *t*, *fig.* 4, about thirty feet long, are bolted to the floor-timbers sufficiently near one another that the *step* (foot) of the mainmast may rest upon them; they serve to relieve the bottom of the ship from the pressure of that mast, and strengthen it against the upward action of the water. The timbers E and F, *fig.* 3, called the sternson and stemson, are also attached interiorly to the stern-post and stem-post, in order to increase the strength of the fabric.

The whole assemblage of rib-timbers is covered on the outside, and either wholly or partly on the inside of the ship, with planks of oak from three to six inches thick; and in order to make the latter bend so as to lie close to the curve surface of the ribs, they are, previously to being applied, moistened by steam: the exterior planking appears in the section, *fig.* 4. The planks are fastened to the ribs both by bolts and trenails (plugs of oak from one to two inches diameter), which pass quite through the ship's side, and are tightened by wedges driven into them at each extremity.

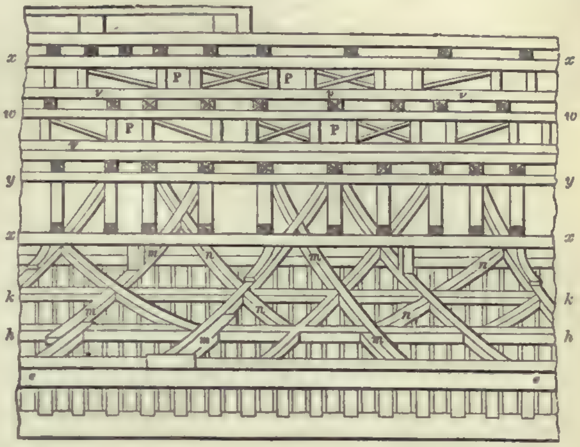
When the ribs do not join closely side by side, it is recommended that, before the planking is applied, the intervals both on the exterior and interior sides of the ship should be filled up with pieces of wood, as long as the curvature of the ribs will permit; the lines of junction with the ribs being well caulked. Sir Robert Seppings, however, proposed that for ships of war, where there are intervals between the principal rib-timbers, there should be introduced in those intervals other ribs extending from the keel up to the orlop or lower deck, since by this construction the lower part of the ship will be one compact mass of timber. He observed that the filling up of the spaces between the ribs not only adds to the strength of the ship by causing its bottom to have a solid thickness, but it tends to preserve the health of the crew, since those openings become receptacles for dirt, by which the air within the ship is vitiated. Channels, or water-courses, may be cut down the ribs at their interior lines of junction, and covered by planks or battens; by these channels the water is able to descend to the limber passage along the keel, and pass to the pump-well. For merchants' ships Sir Robert Seppings recommended strakes, or courses, of thick planks to extend longitudinally through the ship along the interior sides of all the ribs, and to cover the abuttings of the futtock-pieces in each alternate rib: such strakes appear at *n*, *o*, *p*, in *fig.* 4. He considered that no other interior planking would be required, but he recommended that battens should be fastened over the junctions of the ribs in the vertical planes.

A ship being a vast fabric consisting of comparatively short pieces of timber connected together by scarfing, and the principal parts of the frame-work, the ribs, the longitudinal timbers, and the planks being nearly at right angles to one another, it must of necessity happen that when the ship is not supported in its whole length and breadth, it will bend by its own weight. This will take place not only in the event of being lifted up by a wave under some place in its length, or pressed unequally by the force of a wave acting obliquely upon one bow or quarter, but even while floating in still water, from an excess of the weight in one transverse section over that in another. In this last case it has occurred, a horizontal line having been traced from head to stern by means of a spirit-level while the ship was on the stocks, that immediately upon the ship being launched the two extremities were observed to sink as much as three or four inches; the ends of the planks separating in the upper part of the structure, while the timbers below were in a state of compression, and the whole body of the ship becoming curved in a vertical direction. M. Dupin has shown ('Phil. Trans.,' 1817) that the strain is greatest at that transverse section of the ship which divides the whole length into two parts, in each of which the weight of the displaced fluid is equal to that of the corresponding part of the ship and its loading. To counteract the tendency to arch or bend was the object of Sir Robert Seppings in the application of diagonal braces to the interior side of a ship.

Trussing ships to prevent arching was used on the Continent as early as 1759; and the Swedish architect Chapman, who describes the manner of placing the trusses, speaks of the practice as being generally followed. The method consisted in setting up three parallel rows of fir-pillars from one end of the ship to the other; the middle row rested on the keelson, and the others on parallel longitudinal timbers, fastened by bolts to the ribs of the ship, one on each side of the keel; on the heads of these pillars in each row, and under the lower deck of the ship, was placed a longitudinal timber like an architrave; and diagonal braces were placed from the head of one pillar to the foot of the next in each of the three rows. It is evident that such a disposition of braces, if well executed, would serve to prevent or diminish the arching of the ship; but it is far inferior to the method now followed, because of the interference with the loading, and the liability of the pillars to be displaced in consequence of a violent movement of the ship.

In order to understand the construction of a ship and Sir R. Seppings's application of the braces, let *fig.* 5 represent a part, near the mainmast, of a longitudinal section through a large ship of war. In this figure *e e* is the top of the keelson; *h h* and *k k* are timbers extending through the whole length of the ship above the ribs, which are supposed to be close together, and not covered by an interior planking; *m m*, &c., are the principal timbers of the braces; *n n*, &c., are the trusses to those timbers; *x x* is a longitudinal shelf, on which rest the beams of the orlop deck, and the section shows how it is supported on the braces *m m*, &c.; *y y* is a like shelf, on which rest the beams of the lower gun-deck. The beams which support the upper decks rest likewise upon longitudinal shelf-pieces, which appear at *w w* and *z z*; and these lie upon chocks or upon pillars placed against the sides of the ship at intervals between the decks: the same shelf-pieces appear at *x*, *y*, *w*, *z*, in *fig.* 4. Through these and through the ribs pass the bolts by which the iron knees *r r r*, *fig.* 4, are attached to the body of the ship. In small vessels the beams are not always fastened by iron knees, but are merely coaked and bolted to the shelf-pieces: two or more iron knees are however usually placed under the beam near the main and fore masts. The shelves just mentioned constitute as many hoops connecting the ribs of the fabric together longitudinally; they are fastened by trenails and bolts to the ribs and to the beams of the decks: P P, &c., *fig.* 5, are the ports, and the dispositions of the braces between them are shown at *v v*, &c.

Fig 5.

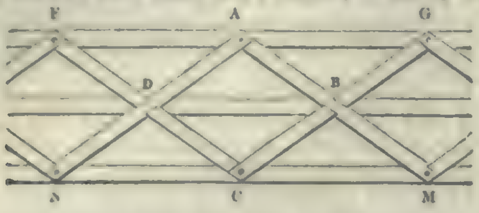


The connection of the two sides of the ship with each other is effected by means of the beams which extend under the decks from side to side. The tops of the iron knees are fastened to these, near their extremities, by bolts passing through them; and the lower parts of the knees are joined to the ship's side by bolts passing quite through the planking, the ribs, the chock-pieces, and the knees themselves. The beams of the principal decks in large ships are usually made in two pieces which abut end to end, and are connected together by having a strong middle piece scarfed and bolted to them. The planks of the gun and upper decks are recommended to be laid obliquely above the beams, and their outer extremities enter into a rebate formed near the interior side of the ship in certain longitudinal pieces which are channelled for the purpose of carrying off the water from the decks: the diagonal position is given to the deck planks, in order that they may increase the strength of the ship in a transverse direction. The exterior planking of the ship is laid on the ribs in longitudinal directions as nearly as possible parallel to the surface of the water; and at the extremities of the ship bolts pass obliquely through them and through the stem-post, the stern-post, and the adjacent rib-timbers.

The oblique timbers, or diagonal braces *m m*, &c. (*figs.* 4 and 5), which are about six or seven feet asunder, cross the ribs at angles of about 45°, and are placed in contrary directions from the middle of each side towards each extremity of the ship. Their upper ends abut against the horizontal shelf under the lower gun-deck, and their heels or lower extremities against the keelson, or against the horizontal timber on each side of it. These braces are attached to the timbers of the ship by cylindrical coaks and bolts, and the lower ends are connected with the keelson by iron straps. The timbers *h h*, *k k*, which are of fir, are attached to the sides of the diagonal braces; and the truss-timbers *n n*, &c., are placed diagonally across the rhomboidal space formed between the principal braces and the longitudinal pieces, in order to prevent the former from becoming bent by the compression which they may suffer endways from any strain which the ship may experience. The diagonal frames, together with the oblique trussing between the ports in the upper works, not only resist the tendency of the ship to become arched, but the former resist also any pressure which may take place externally against the bottom of the ship in the event of grounding; at the same time the exterior planking, the longitudinal timbers, and the oblique planking of the decks bind the whole fabric in one firm body. A close contact of the several parts of the diagonal frames is evidently of the utmost importance, as on it depends the security of the ship against a change of figure.

The principle on which the diagonal braces act may be easily understood from the following considerations:—Let A M, A N, *fig.* 6, be two principal braces; F D and D C, G B and B C, the struts or trusses inserted between them: then if C be the point of support, and if the parts beyond N and M be those which have a tendency to sink by the weight of the superstructure, it will follow from the elements of mechanics, that in this case the braces A M and A N, and the longitudinal timber F G, will be subject to the strain of extension in the direction of their lengths, while the trusses G B and B C, F D and D C, as well as the longitudinal timbers D D and M N, will be subject to the strain of compression. The effect of braces disposed in the positions A M, A N, in midships, and of others corresponding to them towards the head and stern, will be that the strain arising from the weight of the extremities of the ship, and by which arching is produced, is counteracted by the power of the trusses, in positions corresponding to F D and C G, to resist being compressed. A contrary effect would take place if the principal braces were disposed in the directions C F and C G, C being the point supported; for then the trusses between them, and the longitudinal pieces D B, would become disengaged, and would fall out of their places.

Fig. 6.



Sir Robert Seppings's diagonal braces were first introduced in 1810, and his paper on the application of them is contained in the 'Philosophical Transactions' for 1814. They were first applied to the Tremendous; and the success was complete, for after three years' service it was found, by means of lines of sights along the ship, that the gun-deck had not arched in the least, and the upper deck only three-fourths of an inch.

The introduction of iron knees and braces in wooden ships has not only strengthened them considerably, but is a great advantage in the saving of space for stowage. The sheathing of ships at first consisted of a second covering of planks applied, on the exterior of the first, over the bottom and sides as far as they were under water. [SHEATHING.] To save the first expense of copper, a mixed metal called Muntz's Metal, or yellow metal, and composed of 6 parts copper to 4 parts zinc, was in 1832 manufactured at Birmingham under patent, and its use has considerably increased in the merchant service. It has been found that there is a limit to the quantity of copper in this kind of sheathing, as unless the quantity of copper be between 50 and 63 per cent., and the zinc between 50 and 37 per cent., the compound will not roll at a red heat—while too much copper renders the compound difficult to work, and too much zinc renders it too hard when cold. By this use of metal sheathing shells and sea-weeds are partially prevented from adhering to the sides and bottoms; the friction of the water against them is diminished, and the damage which would be caused by worms is avoided.

As further details on the practice of wooden shipbuilding may be obtained from such excellent works as that of Mr. James Peake, of H.M. Dockyard, Woolwich, we only add some information on the manner in which various subjects intimately affecting the whole question of naval architecture have been treated.

In 1814, Mr. Walters, a civil architect, took out a patent for a method of counteracting the arching of a ship by braces of iron, which he proposed to apply on each side of the ship between the rib frames and the exterior planking. The braces were to extend obliquely both ways from the upper-deck beam in midships, in the direction of the line of shortest distance on the surface, towards the keel, where those which were on opposite sides of the ship were to meet under the bows and stern. By this disposition the extremities of the vessel could not sink without putting all the timbers between the trusses in a state of compression, and thus all their joints would be kept close together.

In the 'Mémoire de la Stabilité des Corps Flottants,' published in 1822 by the Baron Dupin, the stability of a ship as derived from difference of form was considered, and has proved useful to the shipbuilder.

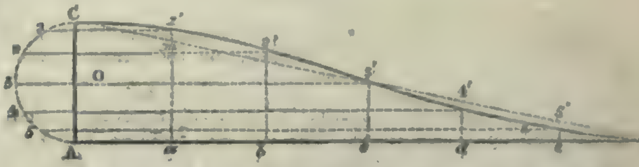
In about 1827, some papers, chiefly contributed by the students of the School of Naval Architecture at Portsmouth Dockyard, were published by Messrs. Morgan and Creuze, formerly pupils of that institution; and as these embodied several valuable translations from foreign authors on the laws of the resistance of fluids, they may still be read with considerable benefit. The Rev. Dr. Woolley, the late principal of that school, and our present great authority in naval mathematics, declared, in a paper read before the Institution of Naval Architects in 1860, that the experiments therein referred to were most carefully made, and entitled to rank among the most important contributions towards the determination of the theory which have ever appeared.

In 1851, Mr. Fincham, the master-shipwright at Portsmouth Dockyard, published a 'History of Naval Architecture,' which throws much light on various branches of the science.

In 1852, Lord Robert Montagu endeavoured, in a small work published by him on naval architecture, to influence the form of vessels by the dissemination of a new theory affecting the question of the molecular motion of water when disturbed by an advancing body. Something similar was also published at New York by Mr. Griffiths. But no permanent benefit to science seems to have been thereby produced; for, as already mentioned, the theory of resistances is still in a very incomplete and unsatisfactory state. The nearest approach to any theory founded on the disturbance of the particles of water is that of the form assumed by the *mass* of water so displaced, and which constitutes the theory announced to the scientific world in 1842 by Mr. John Scott Russell. This, as a question of shipbuilding, is one of paramount interest, intimately connected as it is with that of speed and the various other dependent qualifications of a ship, as influencing the ready defence of the country. Mr. Russell's theory has been already alluded to under RUSSELL, JOHN SCOTT, in the BIOG. DIV. of this Cyclopædia; but an illustration under SHIPBUILDING may be acceptable.

In devising the form of a ship, he proceeds, as already explained at *figs.* 3 and 4; but instead of adopting merely arbitrary changes of area, he arrives at his precise form of midship and load-water curves by the use of a simple and elegant formula, producing thereby curves of contrary flexure, which are said to facilitate the passage of a solid through a fluid. His experiments have shown that although the straight bow of wedge-like form presents actually the smallest surface to the friction of the particles of water, yet that in this form such particles, impinging upon the bow, rebound or are driven off at right angles to the water-line, raising a perceptible wave; while Scott Russell's curve of easy entrance allows the water to roll along the curve to the side of the vessel without such opposition. To illustrate plainly his theory with all possible brevity, let us suppose that, for instance, the area and outline curve of the midship section have been determined: this would represent the greatest beam, not at the centre of the fore and aft line of the ship, but at a point at about two-thirds of the length from the bow. Mr. Scott Russell divides his ship, upon the load water line, into two unequal and dissimilar portions. He considers that the length of midship portion (which, according to his theory, may consist of horizontal lines perfectly parallel to the keel) does not affect, or scarcely affects, any other property than the displacement, the additional friction of such added midship portion being comparatively trifling. Thus his ship, in its abstract original, is merely a bow and a stern; but as the curves which form these are, at their junction at the midship section, tangential, and are parallel to the longitudinal axis, they admit of an easy absorption into the general outline curve of the ship.

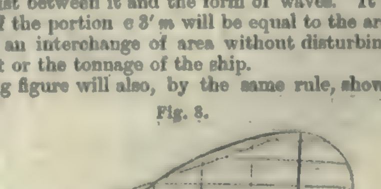
Fig. 7.



Let the line A B represent two-thirds of the whole length of the ship at the load-water line, and be the bow or forward portion, A C representing the half-breadth at her greatest or midship section: join C B. Bisect A C, and from its centre, O, and with O C as radius, describe the semicircle on A C, and divide it into any number of equal parts—say six, for example. Divide A B also into six equal parts, and draw the ordinates a 1', b 2', c 3', &c., parallel to A C. Then draw 1.1', 2.2', 3.3', &c., parallel to A B, meeting the first ordinates at the points 1', 2', 3', &c.; then will these points, 1', 2', 3', &c., be points in the curve which Mr. Scott Russell calls the wave principle, from some analogies which he considers to exist between it and the form of waves. It will be found that the area of the portion c 3' m will be equal to the area of the part 3' B n, forming an interchange of area without disturbing the amount of displacement or the tonnage of the ship.

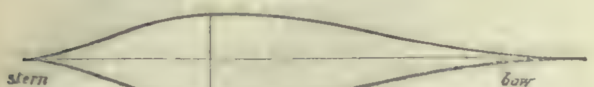
The following figure will also, by the same rule, show the shape of the stern portion of the load-water line, the outline curve being drawn in precisely the same manner.

Fig. 8.



In the figure below we have placed the two ends together (at a reduced scale), to show the whole load-water lines of the ship; and it is remarkable that, in vessels built on the wave principle, the amount of proportionate beam (within ordinary and reasonable limits) is said to very little affect the question of speed.

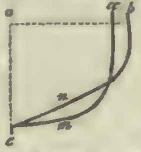
Fig. 9.



Another feature in Mr. Scott Russell's ingenious theory deserves mention. If we divide a ship vertically fore and aft into parallel portions of equal thickness, or, which may be more intelligible to the general reader, if we construct the model of such ship with boards of coloured wood of equal thickness throughout, the lines along the bottom of the ship, formed by the line of junction of such boards, and which are called buttock-lines, are made purposely cycloidal at the stern (the difference in the colour of the woods shows the lines more strongly): such a form of construction is said to facilitate the delivery of water as it passes along the hull.

Sir William Symonds, late surveyor of the navy, greatly altered the form of ships in her majesty's service, although he had much opposition to contend with. We are certainly indebted to him for more height between decks, faster sailing qualities, greater stability, but there are still those who do not wholly admit his theory as fully applicable to heavily armed ships. He gave greater beam, at the expense of hold stowage, &c.—the details of his construction may be seen in an interesting work bearing his name, published a few years since. As a comparison with the prevailing mode of constructing the midship form of section, the following figure will suffice.

Fig. 10.



If *o a* be the beam of a ship of war as usually constructed, he would increase the beam to *o b*, and adopt a very rising floor; while *a m c* would be the shape of the old form, *b n c* would be that of Sir W. Symonds; but this extent of beam has its limits, for although the displacement is taken from the bottom and placed at the load-water line, where it exerts a power of buoyancy, in the ratio of the square of its distance from the fore and aft midship line of the ship, it is said to render the rolling of a ship, under certain circumstances, less easy. But there is no question that shipbuilding received an impetus from Sir W. Symonds, at a time when in England the whole science was in a state of torpor.

Most elaborate investigations as to the mathematical principles involved in the rolling motion of a ship have been recently made by Dr. Woolley. Rolling is manifestly of two kinds, deep rolling and uneasy rolling; the vessel's motion in the latter case is principally affected by the raising of the centre of gravity and the suddenness of the check to oscillation caused by the rapid immersion of the lee-side of the ship, and is often sufficient to endanger masts, and is attendant upon the adoption of very rising floors, for the nearer the midship section approaches a semicircle, the deeper but easier will be the rolling, but this brings us into another extreme, namely, the possibility of danger from capsizing. Dr. Woolley has shown that the mathematical expression for periods of rolling, or as it is called, the theory of rotation, affords no correct indication of the actual condition of a vessel at such times of oscillation.

He gives the following formula:—

$$\text{Time of rotation} = \frac{\pi k}{\sqrt{g\,\mathrm{G}\mu}},$$

where k is the radius of gyration about a longitudinal axis perpendicular to the plane of rotation through the centre of gravity, and $\mathrm{G}\mu$ is the height of the metacentre above the centre of gravity. From which he deduces the following inferences, namely, the smaller the amount of $\mathrm{G}\mu$, or the less the stability of the ship, the longer is the time of oscillation, and consequently the greater the easiness of the motion; while such *case*, however, may, as already observed, be beyond a certain point a source of evident danger. Uneasy rolling may, moreover, be partially corrected by removing weights nearer to the side of the ship, thus increasing the axis of rotation, or as some call it the radius of gyration. The questions of rolling and stability are of great moment to the shipbuilder, as what are called sea-going qualities preeminently hinge on these. The well-known expression for comparison of stabilities is as follows, namely:—

$$\frac{2}{3}\int\frac{y^3\,dx}{\mathrm{D}}$$

when $\int y^3\,dx$ = the summation of the functions of the cubes of the ordinates, dx being the differential of the length of the elementary prism, and D being the displacement. So that in fact the comparative stabilities of ships may be said to be the comparative heights of their metacentres above the centres of gravity.

The rudder serves to govern the ship's motion; for, on being turned so that its plane is in a position oblique to the plane of the masts and keel, the reaction of the water against it as the ship advances, being resolved in a direction perpendicular to the last-mentioned plane, becomes a force which causes the ship to turn upon a line passing through its centre of gravity. Thus by giving the rudder more or less inclination to the said plane, the ship may be made to move in any required direction, or may be made to avoid an object by which its safety might be endangered.

Certain highly interesting facts have been very lately under discussion by the Institution of Naval Architects, aided by the opinions of naval officers of the greatest experience: these will be properly noticed under STEAM-VESSEL.

SHIPS AND SHIPPING. The law applicable to English merchant ships consists of so much of the common law as relates to personalty, the English maritime law to be found in statutes and decisions of her majesty's courts, and the general law maritime recognised less or more by all civilised nations, but peculiar to no one nation in particular. The subject may be conveniently considered under the following heads:—

1. The ownership of merchant vessels.
2. Their navigation.
3. The persons who navigate them.
4. The carriage of goods and passengers.

1. *Ownership. Acquisition of Ship Property.*—Ships, or shares in them, are, in view of the law of England, personal property, which upon the death of the owner passes to his personal representative, and on marriage of a female owner to her husband. Ship property is legally acquired by construction, by purchase, or by capture from an enemy. Very often, perhaps most frequently, the keel of a new ship is not laid down in the builder's yard before a contract has been concluded for her construction between the builder and his customer. Usually, however, all property in the uncompleted vessel continues meanwhile to be vested in the builder, notwithstanding such contract, even although payments be made in advance, and appear to be regulated in accordance with the progress of the work. It is not till she is completed and ready for delivery, and either delivered or approved of, that the rights of ownership vest in the purchaser. Before that time, any instrument executed on his part, with the intention to transfer a title to the ship or any share of her, would be a mere nullity. It is, however, allowed by the law of England to stipulate for a transfer of the property in the uncompleted ship at any stage of her progress, in return for payment of the price in advance by certain agreed instalments; and this is sometimes done.

Purchase of ships already built presupposes in the buyer much skill and no small degree of caution to be perfectly safe. The policy of law in this country respecting bargains is to throw the buyer entirely on his own resources in making the contract, by cutting off all hope of subsequent help out of difficulties into which he never could have fallen if he had used his reason at the time of the purchase. Moreover the difficulties in the way of a purchaser's retrieving himself in case of a bad bargain are increased by the recent statutes respecting the transfer and registration of merchant ships (17 & 18 Vict. c. 104; 18 & 19 Vict. c. 91). A compulsory form of bill of sale is prescribed by the statute, any deviation from which, by the introduction of other particulars, may deprive the buyer of the right of requiring the registration of his title. Warranties, therefore, and representations in the nature of warranties, cannot now be introduced into the only document of contract that can be enforced in a court of law or equity. For any contract, however formal and solemn, other than the authorised bill of sale, although duly executed by both parties, and money paid upon it, gives the buyer no legal or equitable title to the ship, no right to sue in a court of equity for specific performance, or even any right to sue for damages in a court of law on non-performance. This appears to be thought indispensable to any system of effective registration of titles to ship-property.

Registration.—All British ships are now required to be registered, excepting only ships of fifteen tons burden and under, employed on British rivers or coasts, and vessels of thirty tons, not having a whole or fixed deck, and employed in fishing off the coasts of British North America. A British ship is no longer necessarily a British-built ship, or a British-manned ship, but simply a British-owned ship. The persons who are capable in law of being owners of a British ship are (1), natural born British subjects; (2), persons made denizens by letters of denization, or naturalised by or pursuant to any act or ordinance of the Imperial Legislature, or by or pursuant to any act or ordinance of the proper legislative authority in any British possession, provided that while they are such owners they are resident within her majesty's dominions, or members of a British factory, or partners in a house actually carrying on business in the United Kingdom or within the British dominions, and have taken the oath of allegiance subsequently to denization or naturalisation; and (3), bodies corporate established under, subject to the laws of, and having their principal place of business in, the United Kingdom or some British possession. For the purpose of registration, a declaration of ownership is required from the applicant, whose qualification to be the owner of a British ship is thereby ascertained; and any ship sailing under British colours after a disqualified person has become one of her owners is liable to be forfeited and seized into the possession of the crown. Any person making a false declaration as to the qualification of the applicant, forfeits all right which he, or such applicant if cognisant of the offence, possesses in the ship.

A British ship is supposed in law to be divided into sixty-four shares. No one can be registered as owner of a fraction of a share; and no more than thirty-two persons can be separately registered as owners of the ship at one time. Yet a corporate body, no matter how many persons are members of it, is registered as one person: and any five individuals may be registered jointly for the same share or shares, so as to count for one person on the register and no more. If six individuals therefore were to purchase one share, no more than five could appear on the register; the sixth would be a beneficial owner only, and for the purposes of transfer must apply to the five in whom the title is vested. Upon registration of a ship being completed, a certificate of registry is given, indorsed with the particulars on the register; but instead of being, as it was before, the document of title to the ship, it is now no more than is implied in the name, a certificate that the vessel is British-owned and registered, and as such is to remain in the keeping of the master for the purposes of the navigation of the vessel.

The document of title is now the register; all who appear on that book as owners continue to retain the title so declared to be in them as long as they are suffered to remain there, with full power to convey title to any other, and to give valid and effectual receipts for the price. It is not therefore the execution of the authorised bill of sale that secures the property to a purchaser; that bill of sale must be registered, and the burden of that duty is imposed on the most willing shoulders connected with the transaction, namely, those of the buyer himself.

Mortgages of the ship, or any shares of it, are also allowed to be registered, but not trusts or any notice of them. Now as this important book is entirely local, and the necessities of trade might often require the sale or mortgage of the vessel to be effected in a foreign country, or at a distant port in her majesty's dominions, some contrivance was necessary for placing the contents of the register in all their integrity and legal effect before the eyes of the intending purchaser or lender at a distance. This is effected by means of a certificate of sale, or a certificate of mortgage, which is issued upon application by the registrar, containing an exact copy of the details on the register as they appear at the moment of issue. The purchaser or lender is thereby informed of the exact state of the title which is offered, and how far the property is already burdened, if burdened at all. By indorsement on this certificate his title is secured to him, as effectually, and with the same consequences, as if it had been placed on the register at the time when the certificate was granted; and the mortgage takes rank before all other mortgages effected after the issue of the certificate, and not effected by means of it.

Title by Capture.—Title by capture is an acquisition that cannot be made except during war; for capture is the exercise of a belligerent right. But even when exercised during the existence of a war, no more than an inchoate right of property in the captured ship is vested until the capture is succeeded by condemnation in accordance with the principles of the law of nations by a court of competent jurisdiction, sitting by authority of the sovereign of the captors, either in the country to which they belong or in that of an ally in the war. The vessel at the time of condemnation must be lying in a port of that sovereign, or of such ally; for condemnation of her whilst lying in the port of a neutral country, except under very peculiar circumstances, is, according to the English law, a nullity; but the law of the United States appears to differ in that respect, and to have the support of continental practice during the wars at least that followed the first French revolution.

Forfeiture of Ship Property.—Any disqualified person improperly obtaining and continuing to hold shares in a British registered ship, forfeits his shares in consequence; and any ship owned wholly or in part by a person who is disqualified under the law of this country, which assumes the British flag, except for the mere purpose of escaping capture by an enemy, is forfeited to the crown. If any master, for the purposes of his ship, use a British certificate of registry which has not been legally granted in respect of that vessel, he is himself guilty of a misdemeanor, and the ship is thereby forfeited. If anything is done or permitted by the master or owner of a British ship with intent to conceal her British character from any person entitled by British law to inquire into the same—or with intent to assume a foreign character—or with intent to deceive any person entitled to inquire into her national character whilst making such inquiry, and in respect thereof, the ship is thereby forfeited. These forfeitures are authorised by the Merchant Shipping Act of 1854. By the Passengers Act of 1855 (18 & 19 Vict. c. 119) it is enacted that any vessel clearing out to sea without the requisite bond being first executed by the master, or without the requisite certificate of clearance being first obtained, is forfeited to the crown in consequence.

Legal Rights of Part-owners.—If the ownership of a vessel acquired originally in one or other of these ways is not vested in a single person, the several owners, considered as among themselves and not in relation to the register, may hold the vessel in partnership. This, however, is very seldom the case. Usually they are part-owners merely, and as such have no authority by law, any one of them, to bind the rest by his contracts on account of the ship. But if they agree to undertake a trading adventure with the vessel, although they still remain as before, mere part-owners in respect of the hull of the ship, they are partners in the adventure. They are bound to contribute in that case to the expense of the outfit, as being in the nature of capital for the enterprise; and they are entitled to an account at the end of the voyage when the adventure is finished.

The majority in value of the owners of a vessel being authorised by the English law to employ the ship "upon any probable design," are only entitled to do so upon giving security to the minority in a sum equal in value to the united shares of the latter. The mode of obtaining this security is by procuring a warrant from the court of admiralty for the arrest of the ship. After the security has been given, the minority do not share either in the expenses or profits of the adventure. If no application of this kind is made to the court, the minority ought expressly to give notice of their dissent both to their co-owners and all other parties engaged in the proceedings, and they will then be relieved from the necessity of contributing in case of a loss. If they take no steps of the kind, their co-owners, as in the case of any other chattel possessed in common, will not be responsible to them for any consequences short of an absolute destruction by their means of the ship. The same proceedings are proper to be taken where the co-owners are equally divided in opinion, or the minority have obtained possession of the ship. The application for the arrest should be made at the earliest stage of the proceedings, because otherwise the applicant will be held liable to contribute to the previous expenses although he will receive no part of the profits, or even have his application to the court altogether refused.

Agents of the Owners.—For the purpose of managing the ship it is very usual for the owners to concur in appointing an agent who is known to the world thereafter as ship's husband. His powers are very large, considered in the light of the duty for which he is appointed, which is to attend to all matters connected with the outfit and freighting of the ship. It is not, however, within the limits of his authority to effect an insurance. If he make any advances, he can sue those part-owners on whose behalf the advances are made for what is due to him. In case of disagreement among the part-owners as to the settlement of accounts concerning the expenses and earnings of a ship, the ordinary remedy is by a suit in equity.

Another agent who is endowed with very extensive power under certain circumstances to bind the owners by his contract, is the master of the ship. He has power to bind the owners by entering into engagements with third parties relative to the employment of the ship. Such engagements are of two kinds:—1. A contract by which the whole ship is let to hire during an entire voyage, which may be accomplished by a charter-party under seal, or by memorandum of charter-party not under seal. 2. A contract with distinct persons to convey the goods of each, in which case the ship is called a general ship. Such contracts made by the master, being within the lawful scope of his employment, are legally considered to be made by the owners who employ him; and in either case they or the master are liable in respect of these contracts. If the charter-party is made under seal and in the name of the master only, it will not support a direct action upon it against the owners. Still if the contract is duly made, that is, within the usual employment of the master, and under such circumstances as afford either direct proof of authority or evidence from which such authority may be inferred, the owners may be made responsible either by a special action on the case or by a suit in equity. But the master cannot be assumed to have a power to annul an express contract entered into by the owners themselves and to form a fresh contract with other parties.

Besides this power which the master has to bind the owners by his contracts relative to the lading of the ship, he has also authority to render them liable for repairs done and provisions and other things furnished for her use, or for the money which he has expended for such purposes, if they were necessary. In this case also the remedy of the creditor is against the master, unless by express contract he be exempted, and also against the owners. If the contract is made by the owners themselves, they alone are liable. The English law does not follow the rule of the civil law, by which a party who had repaired or furnished a ship had a claim on the ship itself in preference to all other creditors. A party who has done repairs upon a ship has a right to retain the possession of it until his demands are paid; but if he gives up possession, he is on the same footing as other creditors. Where repairs have been done, or necessaries supplied to a ship, the legal owners, although there be proof of their title to the ship, are not on that ground presumed to be liable. There is no presumption of law upon the subject; the matter is altogether a question of evidence; and the question to be decided, in order to determine the liability, is upon whose credit the work was done or the necessaries supplied. If a ship is let out for hire, the owners are no more liable for the work done by order of the hirers, than a landlord of a house would be for work done by order of his tenant. Analogous observations are applicable with respect to the liability of mortgagees and charterers. Where there is an actual letting of the whole ship, and the lessee has the entire control and management of her, the master and mariners being subject to his orders, the lessee becomes for the time invested with the character of owner. But where by the terms of the contract the master and mariners continue subject to the owner, and he through them retains the control and management of the ship, the contract is merely for carrying the lessee's goods.

When, however, the ship is abroad, and the necessary expenses cannot otherwise be defrayed, the master has the same power which the owners or part-owners to the extent of their shares under all circumstances have, to hypothecate the ship and freight as a security for debts contracted on behalf of the ship. The contract of hypothecation is called a contract of bottomry, by which the ship upon its arrival in port is answerable for the money advanced, with such interest as may have been agreed on. By the terms of the contract the repayment of the money is made to depend upon the accomplishment of the voyage, and, in consideration of the risk, the lender is permitted to charge a high rate of interest. By such hypothecation the creditor acquires a claim on the ship. [BOTTOMRY.] When the claim has been created by the master abroad, it may be enforced by suit in the Admiralty Court; but if the ship has been hypothecated by the owners at home, the parties can only have recourse to the common law or equity courts. The Admiralty and the equity courts will recognise the interest of the assignee of a bottomry bond, though at common law he cannot sue in his own name. In general the master has been held not to be authorised to raise money on bottomry within any part of the same country where the owners reside, on the ground that it is his duty to communicate with them before entering into such a contract. But where by reason of hostilities communication with the owners was almost impossible, and immediate necessity existed for the money, which could not be procured otherwise than upon bottomry, a master was held to have authority to raise it on those terms. When money is lent on bottomry, the owners are not personally responsible. The credit is given to the master and the ship, and the remedy is against them only. The master cannot hypothecate the ship for a debt of his own, nor can he give a bottomry bond for matters not within the scope of his authority. If the sums secured by the bond are not repaid, an application must be made to the Court of Admiralty, founded on the instrument of contract and an affidavit of the facts, upon which a warrant issues to arrest the ship, and the persons interested are cited to appear before the court, which then decides what is to be done. If several bonds have been given at different times, the latest in point of time is entitled to be first satisfied, a rule derived from the civil law. ('Dig.' 20, tit. 4, s. 5, 6.) If the necessary amount of money cannot be raised by hypothecating the ship and freight, the master may also sell part of the cargo or pledge it.

Under those circumstances of unavoidable necessity which would authorise the hypothecation of the ship and freight, the master has authority in case of need to hypothecate the cargo for the purposes of the voyage. He may always in these circumstances sell a part of the cargo. He is never allowed to sell the whole for the professed purposes of the adventure, as the adventure is by that very act put an end to; but in case of damage to the cargo, which threatens the destruction of the whole of it before his arrival at the port of destination, he may justify selling part or even the whole, as the only means of saving something for the advantage of the proprietors. To hypothecate the cargo for the purposes of the cargo and the advantage of the proprietors, is within the extent of his powers under proper circumstances, and such a bond executed by the master only is available to the holder by the process of the English Court of Admiralty. To sell the ship is the last conceivable act of a master in circumstances of extreme distress. He will not be justified in doing so, nor can he give the purchaser a good title, if she can be repaired and he has the means and opportunity of doing so, under circumstances in which a judicious man would take that course. But to justify such an act, and make it a binding transfer of property to another, the distress must be so extreme, under circumstances so destitute of assistance, or so void of all occasion for wishing assistance, that either a faithful man can find no better remedy, or a judicious man can wish no other.

Limitation of Liability of Owners.—The liability of the owners under certain circumstances is either limited or altogether taken away by the law of this country.

No owner of any British sea-going ship, or share therein, is liable to any extent whatsoever for loss or damage happening without his fault or privity: 1, of or to any goods, merchandise, or other thing whatsoever taken in, or put on board any such ship, by reason of any fire happening on board such ship; 2, of or to any gold, silver, diamonds, watches, jewels, or precious stones, taken in, or put on board any such ship, by reason of any robbery, embezzlement, making away with, or secreting thereof, unless the owner or shipper thereof, has, at the time of shipping the same, inserted in his bills of lading, or otherwise declared in writing to the master or owner of such ship the true nature and value of such articles.

Where all or any of the following events occur without his actual fault or privity; namely, 1, where any loss of life or personal injury is caused to any person being carried in such ship; 2, where any damage or loss is caused to any goods, merchandise, or other things whatsoever on board any such ship; 3, where any loss of life or personal injury is by reason of the improper navigation of such sea-going ship caused to any person carried in any other ship or boat; 4, where any loss or damage is by reason of any such improper navigation of such sea-going ship caused to any other ship or boat, or to any goods, merchandise, or other things whatsoever, on board any other ship or boat; no owner of any British sea-going ship or share therein, is answerable in damages to an extent beyond the value of his ship and the freight due, or to grow due, in respect of such ship during the voyage which at the time of the happening of any such events is in prosecution or contracted for, subject, however, to this proviso, namely, that in no case where any such liability is incurred in respect of loss of life or personal injury to any passenger is the value of any ship and the freight thereof to be taken as less than 15*l.* per registered ton. The benefit of these provisions is not obtainable, even in our courts, by any foreign ship, nor is it available for a British sea-going ship when sued for injury done by her to a foreign vessel, unless at the time of the accident both ships were in British waters.

2. *The Navigation of Ships. Rules of the Sea.*—For the government of ships in their course over the sea, convenience and necessity early gave rise to certain accustomed practices which have ultimately resulted in rules that are known as the rules of the sea. Those rules, which are still recognised by all maritime nations, were set forth in a notice published by the Trinity House on the 30th October, 1840, in the following terms: "The recognised rules for sailing-vessels is, that those having the wind fair, shall give way to those on a wind; that when both are going by the wind, the vessel on the starboard tack shall keep her wind, and the one on the larboard tack bear up, thereby passing each other on the larboard hand; that when both vessels have the wind large or a-beam, and meet, they shall pass each other in the same way on the larboard hand, to effect which two last mentioned objects, the helm must be put to port." Steam-vessels, for the purposes of these rules were regarded as vessels navigating with a fair wind, and were to give way to sailing-vessels on a wind on either tack. With regard to steamers passing each other, it was at that time the rule that each should put her helm to port, and in narrow channels that a steamer should always leave the vessel she is passing on the larboard hand.

The rules already given are still in force on the high seas among other nations, and consequently must be observed also by British ships when passing a foreign ship. It seemed good, however, to the British parliament to introduce new rules into the Merchant Shipping Act of 1854, which are now compulsory on all British vessels when passing each other. These rules are the following: 1. "Whenever any ship, whether a steam or sailing ship, proceeding in one direction, meets another ship, whether a steam or sailing ship, proceeding in another direction, so that if both ships were to continue their respective courses, they would pass so near as to involve any risk of a collision, the helms of both ships shall be put to port, so as to pass on the port side of each other. This rule shall be obeyed by all steam-ships and by all sailing-ships, whether on the port or starboard tack, and whether close-hauled or not; unless the circumstances of the case are such as to render a departure from the rule necessary in order to avoid immediate danger; and subject also to the proviso, that due regard shall be had to the dangers of navigation, and as regards sailing-ships on the starboard tack close-hauled, to the keeping such ships under command. 2. Every steam-ship, when navigating any narrow channel, shall, whenever it is safe and practicable, keep to that side of the fair-way or mid-channel, which lies on the starboard side of such steam-ship."

A code of rules respecting the exhibition of lights on board, and the use of fog signals, has been published by the Admiralty under the authority of the statute. Steamers between sunset and sunrise are to exhibit a bright white light at the foremast head; a green light on the starboard side, and a red light on the port side, except that when they are proceeding under sails only, the light on the mast is to be dispensed with. Sailing-vessels are to exhibit the red and the green side lights in accordance with the above rule, but no white light on the mast. Pilot vessels are to carry only a white light at the mast-head, and to exhibit a flare-up light every fifteen minutes. Sea-going vessels at anchor in roadsteads or fair-ways, must exhibit, on a conspicuous part, not more than 20 feet from the hull, a white light in an eight-inch globular lantern. As fog signals, sailing-vessels when under way, are in all cases of fog required to use, when on the starboard tack, a fog-horn, and, when on the port tack, to ring a bell, sounding the one or the other respectively, once at least every five minutes; and steamers when under way and their steam up, are to use a steam-whistle before the funnel, sounding it once at least every five minutes; but when their steam is not up they are to use a fog-horn or bell, as in the case of sailing-vessels.

Collisions.—Notwithstanding these rules for the guidance and protection of ships in their progress at sea, and in the fair-ways of maritime traffic, collisions do occur, and questions of fact, difficult to determine, arise as to the existence of negligence in either vessel or in both. It would be quite impossible here to enter upon a detail of cases illustrative of this part of the law. Those who are desirous of considering the subject when exhibited in the occurrences of maritime life must consult those works, the titles of some of which we have appended to this article, in which every help is offered to a complete comprehension of the principles of the law, and their application to facts. The leading rules, however, of the law on this subject may here be succinctly set down. Those of the general maritime law are these, namely, 1, when the injury occasioned is the result of pure accident, the loss lies where it fell; 2, if both parties are to blame, the loss is divided between them; 3, if it happen through misconduct of the suffering party only, he bears his own burden; 4, if it be entirely the fault of the other vessel, the sufferer is entitled to complete compensation for his loss.

By the Merchant Shipping Act of 1854, these rules underwent considerable modification, and since then the British maritime law, which had previously differed from the common law on the subject of negligence, is now identical with it. At common law, a person cannot recover for damage sustained from the negligence of another if his own negligence contributed to the event, or if he might have avoided it by the exercise of ordinary care and skill; but if the other who is sued might, by ordinary care and skill, have avoided the accident, he is liable, notwithstanding there be negligence in the plaintiff remotely connected with the event.

In case of damage done to a ship by another vessel that is in fault, the maritime law gives to the sufferer a lien on the ship that does the wrong. In virtue of that lien, she may be arrested under process of the Admiralty Court, condemned, and sold, and so much of the proceeds of sale applied as is necessary to compensate the owner of the damaged ship; and in case the produce of the sale is not sufficient, the lien extends to the freight being carried by the vessel at the time, and that too may be ordered to be brought into the treasury of the court for adjudication and distribution, pursuant to the law and facts of the case. We have already seen that the liability of British owners is limited, under the supposed circumstances, to the value of the ship and the amount of the freight.

Pilotage; Tonnage.—Immediately connected with the subject of damage by collision is the law of the local pilot. The legislature has made it compulsory on vessels passing over certain pilotage grounds to take one of the local licensed pilots on board, and has at the same time conferred upon the owner, who was thus deprived of his option, an immunity from liability for any damage caused by the ship while she is under the management of such pilot, provided the damage is in no degree attributable to misconduct in the master and crew, or insufficiency of the ship's equipment. The institution of pilots in this country dates from the time of Henry VIII.; and their government is entrusted to the Trinity House, and to certain other pilotage authorities throughout the United Kingdom. It is binding on a pilot to take charge of a ship when required, and on a master to receive such pilot on board when he offers within the pilotage ground, there being at the time no licensed pilot on board. When the pilot takes charge of the ship he is supreme, the master and crew being bound to obey him in all reasonable orders and demands. If the ship is at the time in tow, the tug also is under the orders of the same pilot; and it may be presumed concerning the tug in tow, that if she obey exactly the orders of the licensed pilot in the ship, the owners of the tug are not liable for any damage resulting in consequence. Under these circumstances, it is the pilot who is liable, and his liability in the Trinity House district is limited by Parliament to the amount of his bond, namely, 100*l*. The duty of taking such pilot on board in these particular localities being compulsory on foreign as well as British ships, they participate also in the immunity conferred on the others. [PILOT.]

3. *The Persons who Navigate British Ships. Qualification of Officers.*—A very important change was introduced into the mercantile marine of this country by the Merchant Shipping Act of 1854: the officers of that service are now intrusted with command only upon satisfactory evidence of their qualifications and fitness. Upon testimonials of service, experience, and character, and upon personal examination of the candidates in various departments of knowledge proper to their calling, do the local marine boards distributed throughout the United Kingdom, at all ports of any note, determine week by week upon giving or refusing certificates of fitness to be masters, mates, or first or second mates of foreign-going ships or home-trade passenger ships. These are certificates of competency. Certificates of service as master or mate in British foreign-going ships before the 1st of January, 1851, or as master or mate of a home-trade passenger ship before the 1st of January, 1854, entitle the holders still to serve in the like capacities. A lieutenant, master, passed mate, or second master, or one of any higher rank in her majesty's service, or that of the East India Company, is entitled to serve as master of a British ship. A certificate proper to the rank in which he serves must be held by and be in the possession of the master and first and second or only mate of every foreign-going British ship, and the master and first or only mate of every home-trade passenger ship proceeding to sea from the United Kingdom, otherwise she cannot clear out. And in every such vessel of 100 tons burden and upwards there must be at least one officer besides the master who possesses a legal valid certificate appropriate to the grade of first or only mate of such vessel, or to a higher grade. A penalty of 50*l*. is laid on every one who goes to sea as officer without an appropriate certificate, and on every person who employs anyone to go to sea in such capacity without first ascertaining whether he is so qualified.

Masters' Duties, Powers, and Rights.—In the responsible situation of master of a British merchant ship, his duties are very numerous, onerous, and important. The ship and her cargo are committed to his care, and he is to see that neither take any damage, so far as provident skill and vigilance can prevent or the use of vigorous means can repel. But when prevention is already become impossible, he is then to use all diligence and means in his power to repair the damage, as any judicious man would do for his own property. He keeps his owners constantly informed of his whereabouts, and of the events and incidents of the voyage, enabling them on each occasion to take measures for their own protection and benefit, as they might be advised. He is to give his whole time to their service, and account to them faithfully on his return. The ship's log and official log must be kept under his supervision.

It is his duty to provide for the sustenance, comfort, and health of all persons on board; and if injury accrue through negligence of his in not providing stores, medicines, or proper accommodation, he is liable to an action. His authority on board while at sea is supreme and despotic; and if there be disobedience on the part of the crew, he may correct them in a reasonable manner. On all occasions when discipline is infringed, he will be careful to inquire and inform himself of the true state of the facts before he visit any one with punishment, unless the breach of duty or discipline is obvious to his eyes, and the offence is of that mutinous character which must be checked on the instant with force. He is responsible on his return for all his conduct on board towards others, either on prosecution by public law or at the suits of private persons who have suffered injury at his hands.

His conduct is also liable to be inquired into by the Board of Trade, who have power, if there be occasion, to withdraw his certificate, or by a naval court on the high seas or abroad, who may discharge him and put another in his place.

For his wages, he now has the same lien on the ship and remedies as a common seaman. His disbursements, however, form a mere personal debt. His powers as agent of the owners have already been noticed under the first division of this article.

The Seamen. Ship's Articles.—Apprentices are to be indentured; seamen for foreign-going ships must—and seamen for home-trade ships may—be engaged and discharged before a shipping-master. The agreement of hiring is to be in writing, according to the form, and containing at least all the stipulations, prescribed by the statute. Other stipulations may be added by the consent of both parties; but "no seaman shall by any agreement forfeit his lien upon the ship, or be deprived of any remedy for the recovery of his wages to which he would otherwise have been entitled; and every stipulation in any agreement inconsistent with any provision in this Act (17 & 18 Vict., c. 104), and every stipulation by which any seaman consents to abandon his right to wages in the case of the loss of the ship, or to abandon any right which he may have or obtain in the nature of salvage, shall be wholly inoperative." Although this agreement is in writing, and signed by the seaman, he may prove his case in a court of law without producing or giving notice to produce it; and any erasure, interlineation, or alteration in it, not proved to have been made with the consent of all the persons interested in the change by the written attestation, if made in her majesty's dominions, of some shipping-master, justice, officer of customs, or other public functionary, or, if made out of her majesty's dominions, of a British consular officer, or where there is no such officer of two respectable British merchants, is wholly inoperative. Allotment notes must be stipulated for if required, and may only be granted in favour of the seaman's wife, father, mother, grandfather. grandmother, child or grandchild, or sister or brother; the statute expressly providing that these and these only shall have a right of action on the note. The agreement must contain the following particulars, namely (1), the nature and, as far as practicable, the duration of the intended voyage or engagement; (2), the number and description of the crew, specifying how many are engaged as sailors; (3), the time at which such seaman is to be on board, or to begin work; (4), the capacity in which each seaman is to serve; (5), the amount of wages that each seaman is to receive; (6), a scale of the provisions which are to be furnished to each seaman; (7), any regulations as to conduct on board, and as to fines, short allowances of provisions, or other lawful punishments for misconduct, which have been sanctioned by the Board of Trade as regulations proper to be adopted, and which the parties agree to adopt. Any fresh stipulation on the part of the seamen with the master in the course of the same voyage for an advance in the rate of wages, or for any special gratuity, cannot be enforced, unless the circumstances existing at the time be such as to have cancelled the agreement already made.

Wages.—Wages are no longer dependent on the earning of freight: They may not be attached; and payment of them to the seaman is valid and effectual, notwithstanding any prior attachment, incumbrance, or arrestment thereon, or assignment thereof.

The amount of wages due to the seaman if he fulfil his contract is the full amount originally stipulated therein to be paid him. The voyage, however, is liable to interruption by various casualties; the service of the seaman is subject to discontinuance before the termination contemplated originally on both sides; and it is not a very easy matter in general language to lay down the law which is applicable to each case before it arises. It is not in the power of the master, by wrongfully dismissing any of his crew in the course of the voyage, to deprive them of all or any part of their wages; they may recover the whole, subject to the deduction of such wages as they have earned elsewhere during the period claimed for. But if the ship be lost, or if the mariner quit the vessel for the purpose of taking service in her majesty's navy, he is entitled to the wages due up to the interruption of his service. By desertion, however, or misconduct of a flagrant and serious character, he may forfeit all right to wages. In case death put a period to his service on board during the voyage, it seems his representatives are entitled to be paid wages up to the day of the death, unless the contract made with the owners be such that no right accrues if the seaman do not navigate the ship to the port of destination. The French code, more liberal than our own law, where the hiring is for the voyage, directs payment of half the stipulated amount if the seaman dies on the outward voyage, and the whole if the death happens during the homeward passage.

In virtue of the maritime law the seamen have a lien on the ship for the amount of their wages, which enables them by process from the Court of Admiralty to arrest the vessel, and, unless the owners interpose to pay their just demand, to sell her after sentence of condemnation. The Merchant Shipping Act of 1854 confers the same advantage on the master, who till then had no such remedy. The jurisdiction of the Admiralty Court, however, in claims for wages, is restrained to the case of a contract in the ordinary terms, and not under seal; for if either it be made under seal, or be special in its stipulations, it cannot be the subject of a suit in that court, at the peril of a writ of prohibition issuing from the courts of common law. A further restriction on that jurisdiction is placed by the statute, which prohibits any suit for the recovery of wages, when the sum is under *50l.*, from being instituted in any Court of Admiralty, Vice Admiralty, the Court of Session in Scotland, or any of the superior courts within her majesty's dominions, unless the owner of the ship is adjudged bankrupt or declared insolvent; or unless the ship is under arrest, or is sold by the authority of any such court; or unless any justices, acting under authority of the statute, refer the case to the adjudication of such court; or unless neither the owner nor master is or resides within twenty miles of the place where the seaman or apprentice is discharged or put ashore. In lieu of this, the seaman is now enabled to proceed summarily before any two justices of the peace, or one stipendiary magistrate acting in or near the place at which the service is terminated, or at which the discharge takes place, or, in Scotland, before any such justices or the sheriff of the county, for any sum not exceeding *50l.* over and above the costs. When the engagement is to terminate in the United Kingdom he is not entitled to sue for his wages in any court abroad, unless he be discharged with the sanction of the shipping master, chief officer of customs, British consular officer, or two respectable merchants in or near the place, and with the written consent of the master; or unless he prove such ill-usage on the part of the master, or by his authority, as to warrant reasonable apprehension of danger to life. On his return, however, if he prove either such ill-usage or other misconduct on the part of the owner or master as would have entitled him but for the statutory prohibition to sue for wages before the termination of the voyage, he is entitled, besides his wages, to compensation not exceeding *20l.* in amount.

Discipline. Protective Laws.—We have already seen the authority which is reposed by the law in the master for the maintenance of discipline on board. His power necessarily enables him to inflict punishment for smaller offences upon the instant. In case of the greater offences his power goes no further than to put the seaman, if need be, in confinement, in order to deliver him up on reaching land to the proper authorities, for investigation of the charges made against him, and the consequences which ought to follow thereon. The statute has ascertained the amount of punishment to be inflicted in certain particular cases by the magistrate. The Board of Trade, in certain lesser offences, enables the owners and seamen to agree upon the penalties which the Board have recommended as reasonable and proper to be adopted, and have set out in a schedule published by them in pursuance with their authority under the Act. But no conviction under the Merchant Shipping Act may be made in any summary proceeding, unless such proceeding is commenced within six months after the offence was committed, or within two months after both parties arrive or are at one time within the United Kingdom, or within the jurisdiction of any court capable of dealing with the case in a British possession. Nor can any order for the payment of money be made in a summary proceeding, unless such proceeding is within six months after the cause of complaint arose, or after both parties arrive or are within the United Kingdom, or within the jurisdiction of any court in a British possession capable of dealing with the case. Any local jurisdiction situate on the coast of any sea, or abutting on or projecting into any bay, channel, lake, river, or other navigable water, is extended by the Merchant Shipping Act to any ship or boat being in or lying or passing off such coast, or being in or near such bay, channel, lake, river, or navigable water, and to all persons on board or for the time being belonging thereto, as if such ship, boat, or persons were within the limits of the original jurisdiction. And every offence is to be deemed to have been committed, and every cause of complaint to have arisen, either in the place it was committed or arose, or where the offender or person complained against may be.

The ship's stores, the water on board, and the medicine chest, are subject to inspection by certain public officers. The seaman may complain of the stores and have them inspected, at the peril however of being mulcted in one week's wages in case his complaint be frivolous. In case he is kept on short allowance, not in the way of punishment nor through any fault of the master, but solely from those accidents of the sea that may delay the best provisioned ship that sails, he is entitled to a certain compensation per day while the deficiency lasts. This is rather in the way of wages to him. If he were to be injured, however, by deficiency or badness, either of the stores or medicines, where there is negligence in the master, his right of action for damages is clear. A seaman is not entitled to bring an action because the vessel was unseaworthy and he suffered by it; yet, as the statute provides for his being well and comfortably accommodated, any defect of the ship that should form an encroachment upon such statutory right would be a good ground of action to any seaman suffering injury thereby.

Medicines and medical assistance on board are supplied to the seamen at the owner's expense; and so must they be, also, together with subsistence, if the patient is removed from on board to prevent infection, or otherwise for the ship's convenience, in case he subsequently return to duty on board. If the sickness be the result of injury received in the service of the ship he must be supplied by the owner with medical advice and medicines, subsistence and attendance, until he is cured, or dies, or is brought back to some port in the United Kingdom, or in any British possession, according as he shipped from one country or the other; and his conveyance thereto, or burial, must also be at the owner's expense. It is only when he is absent, however, from the United Kingdom, or the British possession from which he shipped, that the seaman in case of injury suffered in the ship's service is entitled to such assistance; for upon well-known general principles, every servant is presumed to make his contract with a full knowledge of all the risks of the service upon which he is entering.

A most praiseworthy effort has been made to bring the British seaman in every quarter of the globe completely within the protection of the British laws. There is a system of lists of crews for foreign-going ships upon every voyage, and for home-trade ships once every six months, by which a complete register of British seamen is produced, and a somewhat minute knowledge of each individual and his whereabouts is attained. On every sea where her majesty's flag floats over a vessel of war, on every coast where a British magistrate resides, or a British consular officer officiates, there is opportunity for the injured seaman to complain and obtain justice; and any attempt of the master or other officer of his own ship to interfere with or prevent him complaining is an offence punishable with fine and imprisonment.

It is a misdemeanor for a master to force on shore or wilfully leave behind any seaman or apprentice in or out of her majesty's dominions. It is a misdemeanor to discharge any seaman or apprentice at any place out of her majesty's dominions, or in any British possession, except that from which he may have originally shipped, without the sanction in writing of the shipping master, chief officer of customs, British consular officer, or of two respectable merchants resident at or near the place. It is a misdemeanor to leave behind a seaman or apprentice without at the same time obtaining a certificate from such officer or merchants, stating the fact and the cause indorsed on the ship's articles, unless that was impracticable, and the proof of that lies on the master. In case such discharge however be sanctioned, the wages of the seaman are to be paid on the spot by bill or money. And wherever such discharge is rendered necessary by the transfer of the ship at a place out of her majesty's dominions, unless the crew consent to continue with the vessel, it is obligatory on the master to procure a passage homeward for the seaman, or provide him with employment in some other British ship bound for the shipping port in this country, besides paying their wages, and giving them each a certificate of discharge.

Discharges.—The discharge of seamen at home from foreign-going ships is to be before a shipping master. The wages are to be paid in his presence, subject to his cognisance of the rights of both parties under the agreement. No deductions can be made unless the book in which they were entered at the time of forfeiture be produced to the shipping master twenty-four hours before the time of payment. The time of payment fixed by the statute in the case of home-trade ships, is within two days after the termination of the agreement, or otherwise at the time of discharge; and in all other cases, except those where the seaman is remunerated by shares in the adventure, within three days after delivery of the cargo, or within five days after the seaman's discharge, whichever first happens. A mutual release is given by the master and seaman, countersigned and attested by the shipping master; it operates a mutual discharge of all demands in respect of the voyage or engagement, and is the only evidence of the release or satisfaction of any claim required to be thus settled.

Wills.—The wills of seamen have always hitherto been deemed good and effectual although made without writing. No change in this respect has been made that is imperative. But as the Board of Trade are put in possession of the effects of all seamen dying abroad or at sea, that Board may in virtue of the statute refuse to give effect to any will which is not in writing, and signed or acknowledged by the testator in the presence of the master, or first or only mate of the ship, and attested by such master or mate; or if made on shore, unless signed or acknowledged by the testator in the presence of, and attested by two witnesses, one of whom must be a shipping master, minister, officiating minister, or curate of the place; or if there be no such persons, a justice of the peace, British consular officer, or officer of customs. Upon refusal to give effect to any will not so written and executed, the goods and money of the deceased will be distributed among the next of kin under the statutes of distribution.

As to BARRATRY by master or seamen, or both, see the article under that head.

4.—*Of the Carriage of Goods and Passengers in Merchant Ships, the Rights and Duties, &c. of Freighters and Passengers, of Owners and their Servants. The Contract of Affreightment.*—The contracts under which goods are conveyed in a ship are, as has been already stated, of two kinds, the contract by charter-party, and the contract for their conveyance by a general ship. The former is "a contract by which an entire ship, or some principal part thereof, is let to a merchant for the conveyance of goods on a determined voyage to one or more places." A charter-party is a written instrument, not necessarily under seal, which is executed by the owners or the master, or the owners and the master of the one part, and by the merchant or his agent of the other part. The word charter-party is derived from the two words *charta partita*, "divided charter," because the duplicates of the agreement were formerly written on one piece of paper or parchment and afterwards divided by cutting through some word or figure so as to enable each party to identify the agreement produced by the other. If the charter-party is by deed, and executed by the master, and the owners are not parties to it, they cannot bring a direct action upon the instrument; indeed the owners can never bring an action upon it unless their names appear as the parties executing it. But an action may in all cases be brought against the owners for a breach of their duties generally as ship-owners relating to matters not inconsistent with the terms of the charter-party. The charter-party states the port or ports of destination and the freight to be paid, which may be either a gross sum or so much per ton, or so much for each tub or cask of goods. If the agreement is not to pay a certain sum for the entire ship, or a certain portion of it, but to pay so much per ton, the merchant generally covenants to load a fixed amount or a full cargo. The charter-party generally also states the burden of the ship, but this statement, where there is no fraud, is not binding on the parties. The merchant may load with his own goods or those of others, or he may underlet the ship altogether. The master or owner usually covenants "that the ship shall be tight and staunch, furnished with all necessaries for the intended voyage, ready by a day appointed to receive the cargo, and wait a certain number of days to take it on board. That after lading she shall sail with the first fair wind and opportunity to the destined port (the dangers of the sea excepted), and there deliver the goods to the merchant or his assigns in the same condition they were received on board; and further that during the course of the voyage the ship shall be kept tight and staunch, and furnished with sufficient men and other necessaries to the best of the owner's endeavours." The merchant usually covenants to load and unload the ship within a specified time.

The charter-party dates from the day on which it is delivered or signed. The terms generally used may of course be varied so as to meet the intention of the parties. They cannot be altered or suppressed, or others added by any verbal statements, but they may be explained by evidence of the usage of trade in general, or of that particular trade in reference to which the charter-party is made. The charter-party also generally contains two covenants which seem to be wholly inoperative: one, by which the merchant binds himself and the cargo; the other, by which the owner binds the ship and freight in a penal sum, for the performance of their respective covenants. In an action on the charter-party the actual damages proved will determine the amount to be recovered; and they will neither be limited nor extended by the penal sum named; and although by the general maritime law the ship and freight might be made directly available, there are no means for accomplishing that object in this country. As to the cargo, it is always subject to the general law of lien, unless the parties by their contract expressly discharge it.

Under a contract of affreightment doubt often exists as to whether the goods conveyed are in the possession of the party entitled to the payment, and consequently there is doubt as to his having a lien on the goods. The question to be decided is whether the owner has parted with the possession of his ship. If he has entirely surrendered all control over the ship to the merchant who has chartered her, the merchant must be considered for the time as in possession of the ship. The goods on board, therefore, will be in his possession, not in the possession of the actual owner, who accordingly under such circumstances will have no lien on the goods for the payment of the freight. But it must clearly appear from the language of the charter-party taken altogether, and explained by the circumstances of the employment of the ship, that it was intended that such a complete demise of the ship should be made, one of the rules of construction being to interpret such instruments "agreeably to the nature of the contract that a prudent shipowner would make." The right of lien always exists where the freight is to be paid before or on the delivery at their place of destination of the goods, or even, as Lord Tenterden himself decided (2 Barn. and Ald., 603), where there is "nothing to show that the delivery of the goods was to precede the payment of that hire." All these difficulties may be avoided by inserting a clause in the charter-party expressly stating whether it is meant that the owner should have a lien upon the lading for his freight and expenses. The owner does not lose his right of lien by depositing the lading in a public warehouse, provided he gives notice that it is to be detained until his claim for freight is satisfied.

If either party is not ready to perform the contract contained in the charter-party by the time agreed on, he is liable to an action for non-performance of his contract, and the other party may form fresh contracts with third persons.

The charter-party generally contains a clause by virtue of which the freighter is entitled to detain the ship a certain further number of days for the purpose of loading and unloading her, on payment of a fixed sum per day. This payment and the time during which it occurs are both called demurrage: see that article [DEMURRAGE].

When a ship or a principal part of it is not let out by charter-party, the owners contract with several merchants respectively for the conveyance of their goods. A ship so employed is called a general ship. The terms of the contract appear from the instrument called a bill of lading, two or three of which are signed by the master after the ship has been loaded. If any notice or advertisement relative to the destination of the ship has been issued, care should be taken that these are accurate, otherwise the owners may be liable for the consequences of the misstatement. The terms of the bill of lading must be made out according to the direction of the shipper, or, in case a receipt has been given on the delivery of the goods on board, of the holder of the receipt. The form of a bill of lading is stated in a former article. [BILL OF LADING.]

The master on signing the bill of lading should not deliver it except in return for the receipt which he may have given for the goods. By the Bills of Lading Act (18 & 19 Vict. c. 111), every bill of lading in the hands of a consignee or indorsee for valuable consideration, representing goods to have been shipped on board a vessel, shall be conclusive evidence of such shipment as against the master or other person signing the same, notwithstanding that such goods or some part thereof may not have been so shipped, unless such holder of the bill of lading shall have had actual notice at the time of receiving the same, that the goods had not been in fact laden on board; provided that the master or other person so signing may exonerate himself in respect of such misrepresentation, by showing that it was caused without any default on his part, and only by the fraud of the shipper or of the holder, or some person under whom the holder claims. As between the master or owners and the shippers, the bill of lading is in the nature of a receipt, which is only evidence of the matters which it states, and is subject to be contradicted by proof of the real facts. In case of an action for any breach of their implied contract as carriers, against the master or owners, the party who owns the goods mentioned in the bill of lading must be the plaintiff. This will be the consignee of the goods, unless the peculiar circumstances of the case are such as to deprive him of that character. If it is considered necessary to make any provisions relative to demurrage, they are generally inserted in the margin of the bill of lading.

A contract for the conveyance of goods may be rescinded by the act of the parties or by circumstances over which they have no control. If the contract is under seal, it ought, with a view to proceedings in the courts of common law, to be discharged by an instrument of the same nature; but if the facts show an intention in both parties to rescind the contract, a court of equity will interfere in that behalf. Where the goods have been laden and bills of lading signed, the master ought to receive back all the bills of lading or be indemnified against the consequences of having signed them, if the contract of conveyance is to be put an end to: and he has a right, in the absence of any fresh agreement to the contrary, to retain the goods till the freight which he might earn upon them has been paid. If after the contract for conveyance has been entered into, the fulfilment of it becomes unlawful in consequence of some act of the government of the country, such as a declaration of war, a suspension of commercial intercourse, or a prohibition to export, the agreement is dissolved. But nothing short of absolute unlawfulness can excuse the performance of the contract. A contract is not dissolved by the temporary restraint of an embargo, nor, as it seems, of a blockade of the port of departure. But a blockade of the port of destination dissolves the contract, because to sail to a blockaded port with the premeditated intention of breaking the blockade is an offence against the law of nations. If a party has absolutely contracted to furnish a lading for a ship on her arrival at a foreign port, and is prevented from doing so in consequence of any law or regulation merely municipal of the foreign country, this will not excuse the non-performance of his contract: as where the export of the articles contracted to be laden is prohibited, or where intercourse is forbidden in consequence of the prevalence of an infectious disorder. In such cases, and where from any other cause the correspondent of the merchant is unable to furnish a freight, and gives information of that to the master, he cannot, by afterwards remaining at the port the days prescribed, entitle the owners to demurrage.

Passengers.—In all matters that regard the ship, the master has within the scope of his duty an unlimited authority over the passengers as well as over the crew. A passenger may quit the ship, but while he remains on board he is bound in case of necessity to do work that is required for the service of the ship and to fight in her defence. If he thwart the master in the exercise of his authority or otherwise misconduct himself, he may lawfully be put under restraint or imprisoned. If the conduct of a passenger be unbecoming, or if he threaten the master with personal violence, he may be excluded from those parts of the ship which are frequented by the superior passengers, although he has paid such a fare as entitles him to be admitted there. If a passenger feels himself aggrieved by the manner in which he has been treated, he may bring an action against the master, and it will be for the jury, under the direction of the judge, to say whether he has any ground for complaint. In addition to this general right of action, a general statute (18 & 19 Vict. c. 119) has been passed to regulate the conveyance of passengers from places in the United Kingdom to places out of Europe, and not within the Straits of Gibraltar. It regulates the proportion of passengers carried to the tonnage of the ship, provides security for the sea-worthiness, cleanliness, outfit, and proper storing of the ship, for the presence of a surgeon and medicines, for the delivery of a list of passengers to the collector of customs at the port of departure, and attaches penalties to a violation of the regulations which it contains. It also subjects the master to a penalty in case of his improperly landing passengers at any place not contracted for, or wilfully delaying to sail, and provides for the maintenance of the steerage passengers for 48 hours after their arrival at the destined port. The agreement with the passengers must be in writing, and have a scale of provisions attached. Prepayment of the fare by a steerage passenger within the statute is imperative. If a passenger fails to pay his fare, the master or owners have a lien on his luggage for the amount. Nothing is due for the conveyance of an infant born during the voyage. Where there is a contract for the conveyance of men or animals, freight is not due for those which die before the completion of the voyage, unless there be in effect a stipulation that freight is to be paid for the lading of them. The statute provides for the forwarding of all passengers found at any place short of their port of destination, and as this is done at the expense of the owners of the ship that should have conveyed them, all who accept of this kind of assistance forego their right of action against them.

Duties under Contract of Affreightment.—It is the duty of those who have contracted to convey, to do everything and be provided with everything necessary for the safe and expeditious accomplishment of the voyage; and if, through their failure to perform these duties, any damage results to the merchant, they will be answerable for it. At the commencement of the voyage the ship must be sea-worthy, tight, staunch, and sufficient, and properly equipped with all necessary tackle. He who lets the ship is not excused by his ignorance of any deficiency in these respects. The ship must also be provided with a master and crew competent to command and work her, and to guard the cargo on board, and also with a pilot when necessary either from circumstances or from the law of the country. [PILOT.]

It is the duty of the master, unless in case of any usage which relieves him from such duty, to provide things necessary for the lading of the vessel, and to stow away the goods so that they do not injure each other or suffer from the motion or leakage of the ship. The master must procure and keep all documents, papers, clearances, &c. required by the authorities in respect of the ship and cargo; and he must abstain from taking or keeping on board contraband goods or false papers. He must wait during the time appointed for loading the vessel, and, if required, also during that appointed for demurrage. He must pay the charges and duties to which the ship is subject. The statutes 16 & 17 Vict. c. 107; 23 Vict. c. 22; 23 & 24 Vict. c. 110, contain the enactments relative to what is necessary to be done in respect of the custom-house regulations by ships carrying goods from the United Kingdom beyond seas. When all things are prepared, the voyage must be commenced as soon as the weather is favourable. If the ship is to sail under convoy, she must sail first to the rendezvous assigned. Convoy means such ships of war as, in time of war, are appointed by the proper authorities to take charge of trading ships during their voyage to their respective destinations. Before sailing it is the duty of the master to obtain all the sailing orders and other necessary instructions which are issued by the commander of the convoy; and during the voyage to obey these and any others which may afterwards be issued, and to keep company with the convoy. During the time of war it is often rendered imperative upon merchant ships, by acts passed for that purpose, not to sail without the protection of convoy. After the commencement of the voyage, the master is bound, without delays, deviations, or stoppages, to sail direct to the port of destination. But stress of weather, the appearance of enemies or pirates, or the presence of any urgent necessity, will justify him in breaking through this rule; and he ought to do so for the purpose of succouring another ship which he finds in imminent peril or distress.

If the ship is lost or the goods injured during a deviation without any of these grounds of justification, the owner and master will be answerable for the loss to the merchant, even if it does not appear to have been a necessary consequence of the deviation. If the ship during the voyage is so damaged that she is unable to proceed without repairs, the master may detain the cargo, if not of a perishable character, till the repairs are made. If the cargo is of a perishable kind, he ought to tranship for the port of destination, or sell it where she lies if there be no opportunity of transhipment, or that course appear to be obviously injudicious. He may in all cases, where the circumstances require it, exercise a discretion as to transhipping the cargo; as, for instance, when the ship is wrecked or in imminent danger.

Hypothecation of a cargo, like hypothecation of a ship, is "a pledge without immediate change of possession." The party to whom the goods are hypothecated immediately acquires a right to have possession of them if the money advanced is not paid at the time agreed on. This power of the master under circumstances of urgent necessity to sell or hypothecate the goods must be exercised with great circumspection; and the exercise of it can only be justified when it is consistent with what would have been the conduct of a discreet and able man under the circumstances. During the voyage the master is bound to take every possible care of the cargo, and to do all things necessary for its preservation, and he and the owners will be answerable for all damage which might have been avoided by the exercise of skill, attention, and forethought. When the voyage is completed, the master must see that the ship is properly moored, and all things done relative to her which are required by the law or usages of the country. The statutes 16 & 17 Vict. c. 107; 23 Vict. c. 22; 23 & 24 Vict. c. 110, contain the regulations relative to customs to which it is necessary to conform in this country. Upon payment of freight and the production of bills of lading, the cargo must be without delay delivered to the parties entitled to receive it. If the freight due on any goods is not ready to be paid, the master may detain the goods or any part of them.

When the master is compelled, by an act of parliament, to land the goods at any particular wharf, he does not thereby part with the possession of the goods, and consequently does not lose whatever right he may have to detain them. If goods are sold by the custom-house officers before the freight is paid, the master is entitled to receive the first proceeds of the sale in discharge of the freight. In foreign countries, where any accidents have occurred to frustrate or interfere with the objects of the voyage, or any one of the parties to the contract feels himself aggrieved by the conduct of any other, it is customary to draw up a narrative of the circumstances before a public notary. This narrative is called a protest, and in foreign courts is admissible in evidence generally; but in our courts it is not admissible, except as evidence against those who made it.

Non-performance.—Certain circumstances operate as an excuse to the master and owners for non-fulfilment of their contract. "The act of God" is understood to mean those accidents over which man has no control, such as "lightning, earthquake, and tempest." The "perils of the sea," interpreted strictly, apply only to the dangers caused merely by the elements, but these words have received a wider application, and in litigated cases the jury, after hearing evidence as to the usage which prevails among merchants, will determine what interpretation has been intended to be given to them. In the exercise of this discretion, juries have determined that the taking of ships by pirates is a consequence of the perils of the sea; and the verdict has been the same where the loss was caused by collision of two ships without any fault being attributable to those who navigated either of them; and also where the accident was caused wholly by the fault of those on board another ship. But all cases in which the loss happens by natural causes are not to be considered as arising from the perils of the sea. If the ship is placed in a dangerous situation by the carelessness or unskilfulness of the master, and is in consequence lost, this is not a loss from the perils of the sea, although the violence of the elements may have been the immediate cause of it. If a ship is reasonably sufficient for the purposes of the voyage, the master will not be liable for a loss arising from the perils of the sea, because a ship might have been built strong enough to resist them. The "restraint of princes and rulers" is understood to mean a really existing restraint, not one which is anticipated, however reasonably or honestly.

The merchant must use the ship only for lawful purposes, and not do anything for which it may be forfeited or detained, or the owners made liable for penalties. In case of any violation of the agreement, by employment of the ship for purposes other than those contemplated, or failure to perform the terms as to lading, &c., the amount of compensation, in case of dispute, is determined, as the circumstances of the case may require, by a jury. The words primage and average, which appear in the bill of lading, mean, the first, a small sum paid to the master; the second, as there used, certain charges, varying according to the usage of different places, for towing, beaconage, &c.

Freight.—When an agreement for conveyance is expressed in the general form, or when there is no actual agreement, but only one implied by law from the circumstances of the case, there results from it a duty upon the master and owners, first to deliver the goods at the place of destination, whether the ship is hired by the voyage or by the month. It is only by the entire performance of this duty that they can entitle themselves to the payment of freight. The parties may, however, so express the contract that the payment of all or part of the freight may be due before or during the course of the voyage; in such case the word freight is used in a sense which does not properly belong to it; for in strict usage it means only money earned by the conveyance of goods and their delivery at the place of destination. Where a provision is made by the contract for payment of freight at the place of shipment, the question has arisen whether the meaning of the parties was that the sum should be paid at all events on delivery of the goods on board, whatever might afterwards befall them; or whether it was merely to point out the place of payment in case the freight should become due by reason of the arrival of the goods at the port of destination. In all such cases the intention of the parties is a question of construction for the court subject to any usage of the port where it was made, or of the trade with which it is connected. The same observation will apply to cases where money has been advanced by the merchant, and it is disputed whether the money is to be considered as a loan or part payment of the freight.

If the master unnecessarily sell the goods, and so prevent both himself from earning the whole freight, and the merchant from accepting the goods, the merchant is entitled to the entire produce of his goods without any allowance for freight. If the ship has actually never commenced the voyage, the owners are not entitled to any payment whatever, although they may have incurred great expenses in lading her, and though her failure to commence the voyage is not attributable to any neglect or misconduct of theirs. Where the contract of hiring is for a voyage out and home, at the rate of so much per month, &c., during the time the ship is employed, and the contract is entire, no freight is due unless the ship returns home, even though she may have delivered her cargo at the outport. But if the voyages out and home are distinguished in the contract, freight will be earned on the delivery of the cargo at the outport. See further under BILL OF LADING and FREIGHT.

General Average.—If any part of the ship or furniture, or of the goods, is sacrificed for the sake of saving the rest, all parties interested must contribute towards the loss. This contribution is properly called 'Average.' It is sometimes called general average, in opposition to special or particular average, which is the contribution towards any kind of partial damage or loss, or gross average, in opposition to petty average, which is the contribution mentioned in the bill of lading towards the sums paid for beaconage, towage, &c. [AVERAGE.]

The principle of average is recognised in the maritime law of all nations. It was introduced into the civil law from the law of Rhodes ('Dig.' 14, tit. 2, "Lex Rhodia de Jactu;" and the Commentary of Peckius, "In tit. 'Dig. et Cod.,' 'Ad Rem Nauticam pertinentes.'") In order to constitute such a loss as is the subject of average, it must be incurred by design: the masts must be cut away, or the goods thrown overboard; and this must be done for the sake of saving the rest, as in the case of throwing goods overboard to keep the vessel from sinking or striking on a rock, or to lighten her that she may escape from an enemy, or of cutting away a mast or a cable to escape the perils of a storm. The necessary consequences of these acts are also the subjects of average; as where, in order to throw some goods overboard, others or some parts of the ship are damaged; or where it becomes necessary, in order to avoid the danger or repair the injuries caused by a storm or the enemy, to take goods out of the ship, and they are in consequence lost. The expenses also incurred in these operations are equally the subject of average. But the injuries incurred by a ship during an engagement with the enemy, or from the elements in consequence of measures taken to escape from an enemy, are not of such a nature as to fall within the definition. If goods are laden on deck, no average is recoverable in respect of the loss occasioned by throwing them overboard, unless by the usage of trade such goods are usually so laden. If a ship is voluntarily stranded for the purpose of saving her and the goods, and afterwards gets off safely, the expenses incurred by the stranding are the subject of general contribution; but if the ship be wrecked in consequence of the voluntary stranding, there is a difference of opinion whether the wrecking be voluntary, and therefore such a loss as calls for a general contribution. If, in consequence of such an injury done to a ship as would be the subject of average, she is compelled to go into port to repair, the necessary expenses incurred in refitting her, so as to enable her to prosecute her voyage, and the amount of wages, port dues, and provisions expended to accomplish that object, are also the subject of average; and, if the master is unable to obtain the money necessary by any other means than by the sale of a part of the cargo, the loss caused to the merchant upon such sale is also the subject of average. If, in consequence of the sacrifice made, the ship escape the danger which immediately threatens her, but is afterwards wrecked or captured, and the remaining goods, or part of them, are saved or recaptured, these are bound to contribute average towards the loss in the first instance incurred, in proportion to their net value in the hands of the merchant after all expenses of salvage, &c., have been paid.

The things upon which average is payable are, the ship, boats, furniture, &c., but not provisions or ammunition; also all merchandise, to whomsoever belonging, which is on board for the purposes of traffic, but not the covering, apparel, jewels, &c., of parties on board for their own private use. The freight due at the end of the voyage is also subject to average. The goods are to be valued at the price for which they would have sold at the place of destination. If the ship, by reason of what happened when the average was incurred, return to her port of lading, and the average is there settled, the goods are to be valued at the invoice price. The losses incurred by the ship and furniture, &c., are calculated at two-thirds of the price of the new articles rendered necessary to be purchased. The usages of other countries as to all matters connected with average differ in some respects both from those of each other and those of this country. Where the average has been adjusted according to the established law and usage of the country in which the adjustment was made, it is binding upon all the parties to it, unless there be some special contract between them which provides otherwise.

Salvage.—Salvage is that reasonable compensation which persons are entitled to receive who, in the absence of any obligation making it their legal duty, voluntarily save a ship or her cargo from loss by peril of the sea, which may be called civil salvage, or recover them after capture, which may be called hostile salvage. By the law of England, no fixed amount of salvage is laid down as applicable to all cases. What is reasonable can only be determined by a reference to the circumstances. Sir J. Nichol (3 Hag., 'Ad. Rep.,' 117) defines the ingredients in estimating a civil salvage service to be, "1st, enterprise in the salvors in going out in tempestuous weather to assist a vessel in distress, risking their own lives to save their fellow-creatures, and to rescue the property of their fellow-subjects; 2nd, the degree of danger and distress from which the property is rescued, whether it was in imminent peril, and almost certainly lost if not at the time rescued and preserved; 3rd, the degree of labour and skill which the salvors incur and display, and the time occupied; lastly, the value."

Unless in cases where the services have been trifling, the salvage is generally not less than a third and not more than one-half of the property saved; at the same time there is no rule now of specific proportions. If the parties cannot agree as to the amount, the salvors may retain the property until compensation is made; or they may bring an action, or commence a suit in the Admiralty Court, against the proprietors for the amount. In case the property is retained, the proprietors may, upon tender of what they think sufficient, demand it, and, if it is refused, bring an action to recover it, in which action the jury will determine as to the amount due. The costs of the action will be paid by the salvor or the proprietors, according as the amount tendered is or is not determined to be sufficient. The Court of Admiralty has jurisdiction originally in those cases where the salvage has been effected at sea, or within high and low water mark. A passenger is not entitled to salvage for his assistance during the time he is unable to quit the ship. But, if he remain voluntarily on board, he may recover salvage for the assistance which he has given. On one occasion, where a passenger under such circumstances, after the desertion of the master and part of the seamen, assumed the command with the consent of the mate and the remainder, and brought the ship safe into port, he obtained a large sum as salvage. A distinct contract for assistance will do away with any claims for salvage on behalf of the parties who render it. Though a king's ship is bound to assist a merchant ship in distress, it still has a claim for recompense, but cannot prosecute it without the leave of the Board of Admiralty. In awarding salvage, no claims are allowed which are founded on merely prerogative rights, as those of the lord-high-admiral, flag-officers, magistrates, &c.: those claims only are allowed which are made in respect of assistance rendered. The saving of human life cannot of itself be the subject of a claim for salvage, except upon the shore of any sea or tidal water of the United Kingdom (17 & 18 Vict. c. 104); but if it is connected with the preservation of property, that is a circumstance which may affect the amount of salvage. If freight is in progress of being earned, and afterwards does become due, salvage is payable in respect of freight also. When proceedings for salvage have been commenced in the Admiralty Court, the defendants may tender by act of the court any sum which they consider sufficient, and the court will then enter upon an inquiry, and determine what is right between the parties. If the sum tendered has been sufficient, the court may hold the salvors liable to the expenses of the proceeding. With regard to wreck, ships in distress, and for salvage purposes, the Merchant Shipping Act creates receivers of wreck to be appointed at different places on the shores of the United Kingdom for the express purpose of doing all things possible towards the saving of ships in distress, for the recovery and preservation of wreck, and for facilitating the agreement of salvage disputes when the amount is under 200*l.* The receiver may distribute the amount and take receipts if the parties agree; but if not, they may carry their differences before the nearest two justices of the peace, whose decision is final on all sums not exceeding 50*l.* Above that amount, there is an appeal to the Court of Admiralty. If the sum exceed 200*l.*, they may institute the suit in that court in the first instance. Great powers are reposed in the receiver of wreck for collecting assistance, and impressing horses and carts into the service for rendering aid to vessels in distress, for repelling all attempts at violently boarding the ship with felonious purposes, and for the recovery of concealed wreck. Provision is made for cases where no owner of the property appears. Perishable goods may be sold. No lord of a manor claiming a title to wreck can appropriate it until an account in writing of the property, and of the place where it was found and it has been since deposited, has been sent to the nearest custom-house, or if it exceed in value 20*l.* to the secretary at Lloyd's, and a year has elapsed after the delivery of the account. A variety of analogous provisions are enacted relative to goods, parts of ship's furniture, &c., which are found or recovered, whether they may have belonged to ships in distress or not. The statute which relates to the Cinque-Ports is 1 & 2 Geo. IV. c. 76.

In case of capture, by the ancient maritime law the ship and goods became the absolute property of the captor. The old practice in this country was, when ships were in pay of the king, to divide in certain proportions, which varied at different times, the value of the capture between the king, the owners, and the captors. Where the capture was made by ships not in the king's pay, he received no share, but a small proportion was paid to the admiral. In the reign of George II. provision was for the first time made by various statutes for the restoration of the recaptured ship and cargo to the owners, and the rates of salvage were fixed, varying according to the length of time that had elapsed since the capture. In the reign of George III. these rates were done away with, and by various acts the rate of salvage was fixed at one-eighth of the value in the case of king's ships, and one-sixth for private ships; where the re-capture was effected by the joint operation of king's and private ships, the Court of Admiralty were to order such salvage as was reasonable. Convoying ships are entitled to salvage for the recapture of ships which accompanied them. A ship, which has once been used as a ship of war, is not subject to be restored if afterwards recaptured. If a ship is deserted by the enemy after capture and subsequently taken possession of, this is not a recapture, but those who take possession are entitled to recompense as in an ordinary case of salvage. If after the recapture the ship is again taken and condemned, the right of salvage is extinguished. Where the ship of a power in alliance with Great Britain is taken by the common enemy and afterwards recaptured by a British ship, the rule for restitution on payment of salvage is the same as in the case of the capture of a British ship; provided the allied power chooses to adopt that rule in reciprocal cases. If it does not, the same rule which is acted upon in the courts of the allied power is adopted in the British courts. If the ship of a neutral nation be taken as prize by an enemy of Great Britain and be retaken by British subjects, it is restored to the owners without salvage, unless there is reason to suppose that under the circumstances the ship would have been condemned in the courts of the capturing nation. Where it appears that such would have been the case, the British subjects are entitled to salvage. Ships and merchandise taken from pirates are subject, by 6 Geo. IV., c. 49, to a payment of one-eighth of the value. [PRIZE.]

(Maclachlan, *On the Law of Merchant Shipping;* Abbott, *On Shipping,* by Serj. Shee; Maude and Pollock, *Compendium of the Law of Merchant Ships.*)

SHIPWRECKS. That wrecks are numerous, is a fact well-known to a seafaring nation like ours; that they must necessarily be considerable in number, regard being had to the perils of the deep, will of course be admitted; but that nothing can be done to lessen their frequency, would be a hopeless theory of which we ought to be ashamed. Supposing, for the sake of fixing the ideas, that some wrecks are occasioned by a want of scientific knowledge of winds, waves, currents, whirlpools, shoals, reefs, and sunken rocks, on the part of meteorologists and hydrographers; that others are caused by the incompetency of captains and mates; that others again result from the insubordination, carelessness, ignorance, or obstinate fatalism of seamen; that a fourth group are due to the deficiency of lighthouses, beacons, and buoys; and that the remainder arise from want of ready assistance to ships which, though placed in peril on shoals or near rocks, might yet be saved if aid were at hand on the beach or the cliff —who shall say that these evils are incurable? who can put a limit to the improvements which might be wrought?

A dismal story, indeed, does the "Wreck-chart of the British Islands" tell, as published annually by the Admiralty, and afterwards in the 'Life-Boat Journal.' It may be designated a truly distressing map. Every wreck on our coasts has its little black mark; and the aggregate of such black marks reveals the number of wrecks in one year. Knowing that a black spot ● indicates a vessel wrecked, and that + indicates a vessel so seriously damaged as to need to discharge cargo, we look eagerly for the relative numbers of these little spots and stars; and it is saddening to see how numerous are the fatal black signs. At some places the wrecks are numerous because the coast is dangerous; at others, because the congregating of ships is very great. These charts refer only to our own coasts—the coasts of the most busy maritime islands in the world; where, if there be liability of disaster through the vast congregation of shipping, there ought, on the other hand, to be a supply of invention and good sense sufficient to check, in some degree, such disasters. In examining the details of the chart, it will be seen that the line of coast between Dungeness and the Pentland Frith is the most fatal, and that the mouth of the Tyne takes the unenvied precedence of all other places, in the number of black dots and stars opposite to its name; next come the mouth of the Tees and the mouth of the Wear. These three rivers may be taken as the representatives of the district whence three million tons of coal are brought by sea to London yearly, employing the services of several thousand collier ships, which sail to and fro, and add to the otherwise busy commercial trade of the Northumbrian and Durham ports. The mouth of the Humber, the Suffolk coast between Yarmouth and Southwold, the intricate sandy shoals off the mouth of the Thames, the Goodwin Sands, the Scilly Islands, Barnstaple Bay, and Liverpool, are the portions of the English coast which present, in the next degree, the most numerous indications of ship-losses. The Welsh coast is thickly strewn, especially Glamorgan, Pembroke, and Anglesea, Scotland, except in and near the Frith of Forth, presents no large numbers; the western coast is, indeed, remarkably free, due probably to the less exposure to the winds which tend to drive ships ashore on our eastern seaboard. Ireland presents a tolerably equable distribution along the east and south coasts: less on the northern and western.

Many inquiries into the causes of shipwreck have been instituted; and especially one by a committee of the House of Commons. One of the results has been the construction of harbours of refuge, which have not hitherto been very successful. One frequent cause of wreck is collision, arising from bad look out or neglecting to show light. Another cause was the occasional incompetence of the master in merchant vessels. To remedy this, Mr. Cardwell, in 1854, brought in and carried a bill "To Amend and Consolidate the Acts relating to Merchant Shipping;" it constitutes the act 17 & 18 Vict. c. 104, and received the royal assent August 10, 1854. The statute is of great length, and relates to eleven different topics, bearing upon the well-being of sailors and their ships:—the relation of the Board of Trade to the commercial marine; the ownership, measurement, and register of British merchant ships; the qualifications of masters and seamen; the precautions for safety on ship-board; the arrangements concerning pilots; the management and tolls of lighthouses; the constitution of the Mercantile Marine Fund; the laws relating to wrecks, casualties, and salvage; the liabilities of ship-owners; legal course of procedure in the event of misdemeanor; and miscellaneous details. Inspectors of merchant ships, and investigators in respect to wrecks and accidents, are appointed by the Board of Trade; new examinations for masters and mates are organised, separating foreign-going ships from home-trade passenger ships; the Board is empowered to suspend certificates to masters and mates, in case of misconduct or inefficiency; naval courts are instituted abroad or on the high seas, in correspondence with the Board, to inquire into cases of wreck or abandonment of ships; the number and size of the boats to accompany all trading ships are denoted; every ship carrying more than ten passengers must be provided with a life-boat, or an ordinary boat rendered buoyant, and with two life-buoys—the boat and buoys being always kept ready for use; lights and fog-signals are to be used, such as may be suggested by the Admiralty; iron steamers must have water-tight compartments, and safety-valves beyond the control of the engineer; sea-going ships must be provided with fire-engines and hose, signal-guns, and ammunition for firing signals of distress.

Besides the provision for preventing wreck, the Act contains many clauses, applying to cases in which wreck may unhappily have occurred. As these arrangements are somewhat peculiar, it may be well to notice them a little closely. All matters relating to wreck are placed under the general superintendence of the Board of Trade, by whom "receivers of wreck" are appointed. These receivers have the chief command and authority over all persons present at any wreck, or similar casualty, and power to issue such directions as may seem expedient for the preservation of life and property, or for the prevention of plunder and disorder. Whenever a ship is stranded, or otherwise in distress on British shores, bystanders are encouraged to render assistance, by having a pecuniary interest in the preservation of life or property. If services so rendered shall be instrumental towards the object in view, the persons shall have a claim on the owner of the ship for a "reasonable amount of salvage." Numerous directions are given for ascertaining what would be a "reasonable amount" in each case; for enforcing the claim of the salvor against the distrainor; for disposing of an unclaimed wreck; and for adding to the salvor's reward out of the Mercantile Marine Fund, in cases where life has been preserved, and where the wrecked ship is insufficient in value to pay the salvage awarded. The Mercantile Marine Fund here adverted to is made up in a curious way: it consists of certain fees received by the Board of Trade for examinations and registries connected with merchant-ships; lighthouse dues accruing by virtue of certain sections of the Act; rates accruing from lastage and ballastage in the Thames; and fees derived through the receivers of wreck. The fund, kept by her Majesty's Paymaster-General, is employed in payment of the salaries of examiners, surveyors, receivers, &c.; expenses in regard to lighthouses, buoys, beacons, lastage, ballastage, life-boats, &c.; and rewards to persons who assist in saving wrecked ships, or crews, or passengers.

Wrecks, however, will still occur on our coasts, and the necessity arises for affording assistance. By the efforts of the National Life-Boat Institution, which has received the support of the government, life-boats have been placed at most of the dangerous parts of our coast. [LIFE-BOATS.] But there are times when other aid is needed; when a ship is in distress so near the shore as to be within reach of a rope, if means were at hand to throw it—while, perhaps, no boats are near the spot fitted to render the required service. What are the crews to do? Sailors, unfortunately for themselves, are in too few cases swimmers; and even a swimmer has a poor chance for his life in such weather and such a sea as usually accompany these strandings of ships. The men generally cling to their vessel as long as her timbers will hold together, rather than strike out and endeavour to swim to shore. In such case their safety mainly depends on the establishment of some communication with the shore. Such communication was the object of Captain Manby's attention, and his name is intimately associated with the history of this part of the subject. He had, in 1783, thrown a line, by means of a small mortar, over Downham Church, in Norfolk; and it struck him that he might, by the same means, throw a line over a stranded vessel. During many subsequent years he made repeated experiments; his main difficulty consisted in securing the shot to the rope; iron chains were liable to break on the discharge; but at length he found that stout strips of closely-plaited raw hide would answer the purpose. The rocket apparatus is now thoroughly effective, and many thousand lives have been saved by means of the ropes thrown out to stranded ships, through the agency of mortar-rockets. There are upwards of 200 places on the shores of the United Kingdom, where such apparatus is kept, mostly under the charge of the coast guard, who, from the peculiar nature of their other duties, are well adapted for this kind of service.

SHIRE, from the Saxon *schyran*, to divide (whence also *to shear*), is the name of districts into which the whole of Great Britain is divided. The word shire is in most cases equivalent to *county*, a name often substituted for it in Great Britain, and always in Ireland. The origin of this distribution of the country cannot probably now be ascertained. It has been customary to attribute it to Alfred, upon the authority of a passage in Ingulphus, the monk of Croyland, who wrote about a century and a half after the reign of that king. Asser, however, the biographer of Alfred, does not mention this most important fact, and the unsupported statement of Ingulphus is of little value. In truth, shires were certainly known before Alfred's time. Sir Francis Palgrave shows them to be identical, in many cases, with Saxon states; thus Kent, Sussex, Essex, Norfolk, Suffolk, Middlesex, and Surrey, were ancient kingdoms: Lincolnshire, under the name of Lindesse, was an independent state, and Worcestershire (*Huiccas*) was the jurisdiction of the bishop of Worcester. Shires of another class were formed out of larger divisions, either for the sake of more easy management when the population of the particular district had increased, or for the sake of giving territory to an earl. Yorkshire was part of the kingdom of Deira, and Derbyshire of Mercia. Lancashire was made a county subsequently to the Conquest. On the other hand, some shires have merged in others; Winchelcombeshire is a part of Gloucestershire; and in the Act for abolishing the palatine jurisdiction of Durham (6 & 7 Will. IV., c. 19) no less than five shires are mentioned, namely, Craikshire, Bedlingtonshire, Norhamshire, Allertonshire, and Islandshire; which had long ceased to possess, if indeed they ever enjoyed, separate jurisdictions.

The uses of the division into shires may be learnt by an enumeration of the principal officers in each:—1, the lord lieutenant, to whom is entrusted its military array [LORD LIEUTENANT]; 2, the custos rotulorum, or keeper of the rolls or archives of the county; this officer is appointed by letters-patent under the great seal, and is now always identical with the lord-lieutenant, except in counties of cities, where the high steward is usually custos rotulorum; 3, the sheriff, or, as he is often called, the high sheriff [SHERIFF]; 4, the receiver-general of taxes, who is appointed by the crown, and accounts to it for the taxes levied within his district; 5, the coroner [CORONER]; 6, the justices of the peace, whose commission extends only to their own county, and who, assembled in sessions, have jurisdiction over many offences, and control over the county funds [SESSIONS]; 7, the under-sheriff, who is appointed by and performs nearly all the duties of sheriff; and 8, the clerk of the peace, an officer (almost always an attorney) appointed by the justices in quarter-sessions, whose duty it is to file and produce recognisances, returning them, when forfeited, to the sheriff to be levied [RECOGNISANCE]: he likewise prepares or files indictments to be tried at the sessions or assizes, and in general acts as the officer of the justices in quarter-sessions.

County-rates are assessments made by the justices in quarter-sessions assembled, according to estimates laid before them. The principal objects of these rates are: the building and repair of bridges, jails, shire-halls, and courts of justice, and of late years lunatic asylums; the repair of roads; the payment of the salaries of the coroner, clerk of the peace, high and special constables, jailers, &c.; the expense attending the apprehension, conveyance, and prosecution of persons accused of crime; and under this head is included the remuneration to witnesses for their loss of time and expenses; the maintenance of prisoners, and their transportation. The rates are levied by collectors, and enforced by the sheriff.

The judicial tribunals in each county are the assize court [ASSIZES]; the old schyremote or county-court held for the election of knights of the shire, and the hundred courts, and courts-leet. [COURTS.] These hundred courts and courts-leet have long been almost entirely obsolete, and the county court statutes accordingly contain provisions for their surrender to the crown.

The principal subdivision in a county is the hundred, a district which in its origin bore relation rather to the population than to any uniform geographical limits. Mr. Hallam considers it to have been a district inhabited by 100 free families, and that a different system prevailed in the northern from that of the southern counties; in proof of which he contrasts Sussex, which contains 65 hundreds, and Dorsetshire, which contains 43, with Yorkshire, which contains only 26, and Lancashire, only 6. In the counties north of the Trent, this subdivision is often called a wapentake. That the division into hundreds was known among the Germans, even in the time of the Roman invasion, is argued from two passages in Tacitus ('De Mor. Germ.,') "ex omni juventute delectos ante aciem locant—Definitur et numerus; *centeni* ex singulis pagis sunt." And again, "Centeni singulis (principibus) adsunt ex plebe comites, consilium simul et auctoritas." "Nihil nisi armati agunt;" and hence Spelman infers the identity of the *wapentách*, or military array (taking of weapons) and the hundred court. Sir Francis Palgrave says that the burgh was only the enclosed and fortified resort, the stockade of the inhabitants of the hundred. The subdivision of the hundred was the tithing, composed, as it is alleged, of ten free families, and having for an officer the tithing-man, a head constable.

Whether in the barbarous times to which it is attributed, so elaborate a system as we have sketched could have prevailed, is at least most doubtful; but the theory is that somewhere about the time of Edgar (A.D. 950), the county was divided into tithings, of which 12 made a hundred—for the Saxon hundred meant 120, and hence perhaps the frequent use of the number 12 in our legal processes. These hundreds were presided over by their decanus, or headborough, or hundred-man, and were represented in the shiremote; and this aggregate body, the shire, presided over by its earl and bishop or sheriff, conducted its own internal affairs.

There are three counties-palatine, the earl of which had within his shire all the fiscal and judicial powers of the crown:—Chester, created by William the Conqueror; the duchy of Lancaster, created by Edward III.—these two have been long annexed to the crown; and Durham, formerly governed by the bishop, but annexed to the crown in 1836. In this year a part of the see of Ely, which had been a royal franchise, was annexed to the crown, as Hexhamshire in Northumberland had been in the reign of Elizabeth. [PALATINE COUNTIES.]

SHODDY MANUFACTURE. This has recently become a large and important branch of industry in the West Riding of Yorkshire. *Shoddy* and *mungo* are the strange names given to two varieties of rag-wool; the one being obtained from old blankets, carpets, flannel, and worsted stockings; and the other from tailors' cuttings and worn-out woollen garments. In both cases, the pieces are torn up fibre from fibre, constituting a kind of dirty short-stapled wool. There is a third variety called *extract*, obtained from "union" or "mixed" goods, in which cotton is woven up with wool; rags of this kind are exposed to the action of strong chemical agents, which completely dissolve away the cotton, and leave the wool behind.

So far back as half a century ago, cloth manufacturers began to mix a little rag-wool with new wool in the making of cheap cloth; but it is only in recent years that a large and distinct branch of industry has resulted therefrom. At the present day, Batley and Dewsbury are the centres of the trade, giving employment to many thousand persons in several mills—in producing shoddy and mungo from rags, in sorting and preparing rag-wool imported from abroad, or in spinning the old with the new wool into yarn for weaving into cloth. Besides the two towns here named, the manufacture is distributed throughout the whole of the surrounding district—in Ossett, Mirfield, Morley, Earlsheaton, Heckmondwike, Gomersal, Elland, Stainland, and other places scarcely known even by name out of Yorkshire, but gradually rising from mere villages to the dignity of towns. The trade is a very dirty one. The rags have gone through a long period of service, and are unavoidably soiled and stained in various ways. There are sorters, whose business it is to classify the rags into as many kinds and colours as possible, in order that manufacturers may be able to select the varieties which best suit their purposes. There are also cutters, whose employment consists in cutting off knots and seams, which would otherwise interfere with the operations. The disentanglement of the rags into rag-wool is effected chiefly by a machine called a *swift*. This consists of a revolving cylinder, set with iron-toothed plates; the rags are fed in at one point, and are torn into fibres by the action of the teeth. Some of these machines contain 14,000 teeth, perform 700 revolutions per minute, and are employed in grinding up good woollen rags into mungo; others, with fewer teeth and a slower motion, tear up old worsted rags into shoddy. Each machine produces on an average about 1000 lbs. of rag-wool per day. In the township of Batley alone, it is estimated that there are now from 12 to 14 million pounds produced annually; about an equal amount in various places within four miles of that town; and again an equal amount in places beyond that limit—in round numbers, 50 million pounds of woollen and worsted rags are disentangled into 40 million pounds of mungo and shoddy. Of the whole quantity, about one-third is mungo, of an average worth of 6*d*. per pound; and two-thirds shoddy, worth 4*d*. This amounts to the large sum of nearly 800,000*l*.—a value wholly superadded to that which relates to new wool. A great portion of this is absolute saving to the community: for woollen rags possess only a very small per-centage of this value, when applied to other manufacturing uses.

Mungo and shoddy are not used alone in making woollen goods. New wool is added to them, to give them the felting property and strength of fibre. The very commonest goods may have eight or ten times as much rag-wool as new wool; in medium goods the ratio may be nearly equal; in a higher class of goods there may be eight or ten times as much new wool as rag-wool. It is all a matter of price. One cause for the (apparent) cheapness of woollen goods within the last few years is the large admixture of mungo and shoddy. None but a skilled person can detect this admixture; and in some cloths, indeed, mungo is combined so judiciously with new wool as to produce a really strong material. Mungo made from the best woollen cuttings is, in fact, better than new wool of low quality; and cheapness is here something more than a name. The kinds of cloth chiefly produced, having mungo or shoddy as part of their substance, are numerous, and receive designations conveying very little information except to those engaged in the trade; such as tweeds, flushings, paddings, duffels, friezes, witneys, mohairs, pilots, petershams, strouds, savelists, reversibles, linings, sealskins, doeskins, cheviots, &c. The most extensive branch of the manufacture is that of pilots, a cloth employed in making the heavy substantial "pilot coats" used by sea-faring men. These, like the rest, may have much or little shoddy in them, according to the price to be charged.

The processes need not be described here. They partake of the same general character as those treated under Woollen and Worsted Manufacture. (Jubb, 'History of the Shoddy Trade,' 1860.)

SHOE TRADE. Under Boot and Shoe Manufacture, some of the mechanical features of this branch of industry were noticed. In the present article we shall treat briefly of the relation between the different kinds of workpeople, and of the changes recently effected through the introduction of sewing-machines.

A shoemaker, in the old statutes, is called a cordwainer, apparently a corruption of the French *cordonnier*, which means a worker of Cordova leather. The companies of shoemakers in our ancient towns were incorporated under this name; and where some of these companies still exist, they go by the same name. As a legal term cordwainer is still common. The law of England formerly took cognisance not only of the quality of the leather which the shoemaker wrought into his goods, but of the number of stitches that he furnished.

The trade, as now followed in London and other principal places, is subdivided into about twenty branches. The following may be set down as the chief: the *shoeman*, or maker of the sole part of the shoe; the *bootman*, or maker of the sole part of the boot; and the *boot-closer*, or joiner together of the leg, vamp, &c. The labour of these is especially directed to what is called the *men's line;* whilst others make the ladies' shoe or boot. There are many women, too, who get a livelihood by closing the shoe; while others again practise the various sorts of binding. In the manufacture of a boot, the clicker or cutter having designed and cut the leather of the vamps, legs, &c., to the measure of the customer or the size wanted, the materials go to the closer. Much of the boot-closer's art, as now perfected, is of a very delicate nature, especially in the putting together or closing of all the parts of the top-boot, and the fancy-wrought and coloured Wellington; the common Wellington being the easier portion of his occupation. The bootman does for the boot what the shoeman does for the shoe; he makes or attaches the sole. The labour of this person, however, is much better paid than that of the shoeman; because it has a higher character, and considerably more time is required to complete the article. The best shoemen usually at the first opportunity take to be bootmen. The making of the woman's common or welted shoe resembles that of the man's; and where it differs it is unnecessary here to explain. The man's and woman's single-sole shoes or pumps are also proceeded with in the same manner.

Formerly it was the general practice for the journeyman to work in the shop with his employer; two, three, six, or more, all working together. The journeymen then had sometimes, as now, so much per pair; but he was also paid by the day or week, or was even engaged as a quarterly or half-yearly servant. In every case he had his coals and candles in winter, and in all seasons his finding or grindery free, that is, his hemp, wax, paste, bristles, &c. Wages then were very low; but the work was of an inferior description, and the habits of the time very plain and simple. Towards the end of the last century, the shoemaker's position improved. He gave up working in the shop of his master, or in garrets with several other men. If married, he followed his employment in his own home. If unmarried, he joined himself in a sort of partnership with another workman in a like condition, and taking a furnished lodging, felt more at ease than under the former system of constraint. This still is the practice among the better-paid classes of the trade.

In Boot and Shoe Manufacture, the recent importations of boots, shoes, goloshes, and boot-fronts from foreign countries are noticed. The *exports* from the United Kingdom are not so easily determined, seeing that boots and shoes are in this instance included under the general designation of leather "wrought and unwrought," exclusive however of "saddlery." The return under this head for 1860 was 6,473,826 lbs., having a declared value of 1,407,557*l*. It is computed that about two-thirds of the above quantities consist of boots and shoes, which are exported chiefly to Australia and the other colonies. Mr. M'Culloch, in the latest edition of his 'Commercial Dictionary,' expresses an opinion that the boots and shoes now made annually in the United Kingdom have an aggregate value of 10,000,000*l*.; of which he sets down about one-half for wages, and the other half for materials and profit.

In the article just cited, it was stated that, in 1859, a struggle had arisen between the masters and men concerning the employment of sewing-machines. The masters have now (1861) gained their point, as they are always likely to do where labour-saving contrivances are in question. According to information given in an article by Mr. Charles Knight, in the 'Companion to the Almanac' for 1861, the workmen are gradually yielding, seeing that opposition is of no avail. It was supposed in 1851 that no less than 30,000 persons were in various ways employed by the Northampton boot and shoe-makers alone; and since that year the trade has extended greatly, both at Northampton and Stafford, and in various villages surrounding those two towns. In the large factories, the upper leathers are now to a considerable extent put together by the aid of the sewing-machine; the machines belong to the employers, and there are often fifty or sixty of them in one room. The women employed at the machines earn much more than by hand-sewing; but of course not so many of them are needed. Some of the manufacturers are of opinion that the machines are not suited for men's strong shoes, on account of a difficulty in using waxed thread; but others believe that the machines will gradually impart a wholly new aspect to the trade. The "Northamptonshire Boot and Shoemakers' Mutual Protection Society" was unable to stem the current; and the machines are now employed, not only in the large factories, but by the workpeople themselves. "A dealer in the machines informed me," says Mr. Knight, "that a few provident shoemakers were purchasing the machine for the domestic employment of their families, by which one female of their household would be able to earn more than was formerly earned by the wife and two or three daughters. The advantage would not rest here. The wife would be at liberty, by working a few hours a day at the machine, to have leisure for her domestic duties; and would thus obviate the reproach attached to too many shoemakers' wives, that the dirty home, the slatternly habits, and the neglected children, drive the husband to the public-house. The machines cost from 12*l*. to 25*l*. I saw one which the dealer in machines was about to sell to a steady workman, upon his paying the cost by instalments." The apparatus will be found briefly described under Embroidery and Sewing Machines.

The Americans carry on the shoe-manufacture on a scale not equalled by anything known in this country. A large steam-factory for the purpose has been established at Haverhill, in Massachusetts. In the basement story are machines for cutting, rolling, and shaping the leather for shoe-soles. In the next story the upper leathers are lasted, and the outer soles tacked on. In another range of rooms are the pegging machines; long strips of wood, of the required width, are coiled up, and put into each machine; the machine uncoils the strip, cuts it up bit by bit, makes holes in the shoe, and drives a bit as a peg into each hole; this is effected at the rate of fourteen pegs per second. In other rooms are stitching machines worked by steam.

SHOOTING STARS. [Meteors.]

SHORT-HAND. [Stenography.]

SHORT-SIGHTEDNESS. [Sight, Defects of; Spectacles.]

SHOT are the balls (generally solid) of iron which are discharged from guns, howitzers, or carronades. Those which are used for the first of these kinds of artillery vary in diameter from 1·955 inches, which is that of a one-pound ball, to 7·95 inches, which is the diameter of a 68-pound ball. Shot for howitzers vary in diameter with the nature of that arm, from 4·476 inches, which is the diameter of a 12-pounder howitzer, to 9·88 inches. Carronades, which are now never used, discharged balls weighing from 6 lbs. to 68 lbs., which were of course equal in diameter to those which belong to guns of equal calibre. Hollow shot have latterly been introduced into the service, principally for the navy. The guns for throwing hollow shot are 8- and 10-inch, and are sometimes called Paixhans, from the inventor; though not so light as the howitzers of those calibres, they are lighter than solid-shot guns. They can be used for throwing both shells and hollow shot with small charges. Hollow shot, or unloaded shell, as they are in fact, have this advantage, that though their diameters are large, their weights being small, a small charge gives a high initial velocity, rendering them very effective for short or ordinary ranges, while from their large size they are capable of producing most destructive effects, more especially on shipping. The shot for Rifled Ordnance are described under that head.

SHOT MANUFACTURE. [Lead.]

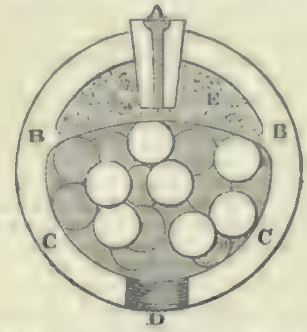
SHRAPNEL SHELLS, so called from the inventor, Major Shrapnel, R. A., are a most destructive description of projectile; they are principally used against skirmishers and scattered bodies of troops beyond the range of common case, 300 yards, or of grape shot, about 600 yards.

A Shrapnel shell or spherical case shot, consists of a thin shell of cast iron, containing a number of musket balls and a small charge of powder just sufficient to burst it, and free the balls; a Fuze, by which the charge is ignited and the shell burst at the proper instant, is fixed in it, as in an ordinary shell.

The effect of the musket bullets in the Shrapnel is due to the velocity imparted to them by the gun, and not by the bursting charge which only frees them. A spherical case shot when loaded is about the same specific gravity as a solid shot of the same diameter. A musket ball is effective when impelled with the same velocity as that retained by a solid shot from a 6-pounder or 9-pounder at a range of about 1200 yards. If therefore the spherical case shot be projected by the ordinary service charge, and be made to burst at any distance up to 1200 yards, the musket balls which it contains being freed, will, spreading out like a fan, and covering some extent of ground, strike effectively. For at the instant of the explosion they have the velocity of the shell, and they will proceed forward, generally in the direction in which the shell was going, for the path of the common centre of gravity after explosion will (disregarding the greater effect of atmosphere) be the same as that of the shell before the explosion, and the velocity with which the bullets strike will be the same as that of shell, or at least sufficient to make them effective.

The common spherical case was attended with many inconveniences, and in the larger descriptions of ordnance more especially, was very liable to burst in the gun. This was supposed to be caused by the shell, which was necessarily thin, not being strong enough to resist the explosion of the full service charge; the charge was therefore reduced, but the experiment, besides not being always successful, had the disadvantage of reducing the velocity so much that the bullets were not effective. Captain Boxer, R. A., showed that the cause of the shells bursting was the concussion caused by the different relative motions of the external case and the bullets in the interior, when the former was first put in motion by the charge—a concussion sufficient to ignite the charge of powder. He therefore invented the diaphragm shell, in which the bursting charge is kept separate from the bullets in a chamber formed by a thin iron diaphragm fixed in the shell when it is cast.

The form of the shell will be readily understood from the accompanying cut. It has been found perfectly efficient. The Shrapnel from the Armstrong guns is described under RIFLED ORDNANCE.



Section of Boxer's Diaphragm Shrapnel Shell.

A, the fuze; B to B, the diaphragm; C, C, shell; D, the aperture for inserting bullets, which is afterwards plugged; E, the bursting charge inserted at fuze hole.

SHROUDS. [SHIPBUILDING.]

SHROVE-TIDE, or SHROVE-TUESDAY (from the Anglo-Saxon *scrifan*, to confess), signifies the time of confessing sins; for which purpose this day was anciently set apart by the church of Rome as a preparation for the austerities of Lent. This season was likewise called *Fasting-tide, Fastens*, and *Fast-mass*, by all of which titles it is yet designated in different parts of the North.

In the Reformed Church the ancient practice of shriving or confessing at Shrove-tide is discontinued.

After the people had made the confession required at this season by the discipline of the ancient church, they were permitted to indulge in festive amusements, although not allowed to partake of anything beyond the usual substitutes for flesh; and hence arose the custom yet preserved of eating pancakes and fritters at Shrovetide, which has given this day the vulgar appellation of Pancake Tuesday. The Monday preceding was, by the vulgar, called Collop Monday, a name which it even yet retains in some places from the primitive custom of eating eggs on collops or slices of bread, which the less scrupulous and more luxurious moderns have extended to collops of meat.

On these days of authorised indulgence all kinds of recreations were tolerated, provided a due regard was paid to the abstinence commanded by the Church; and from this origin sprang the Carnival. [CARNIVAL.]

To the pastimes of this early age are also to be traced the diversions of football, cock-fighting, and cock-throwing, as well as the discontinued customs of whipping-tops, roasting of herrings, Jack of Lent, &c., which three last-named sports were evidently meant as types of the rigour of church discipline. The cock-fightings and cock-throwings in England, which have gone into disuse, were once general throughout the kingdom at this season.

(Brady's *Clavis Calendaria*, vol. i.; Brand's *Popular Antiq.*, vol. i.)

SI, in music, the name given by the English, Italians, and French to the seventh of the syllables used in solmisation; and, by the two last, also to the note, or sound, called B by the Germans and English. [SOLMISATION.]

SIALAGOGUES (from *σίαλον*, "saliva," and *ἀγωγός*, "that which leads or brings"), agents which increase the flow of saliva and other fluids from the parotid and other glands in the vicinity of the mouth. They operate in different ways, and are distinguished into local or remote. Of the local, some are gaseous, others are solid; these last are also termed *masticatories*. Of the gaseous, the most familiar is the odour of savoury food, which produces an immediate secretion from the salivary glands, being the primary step in the process of digestion, for the perfect performance of which thorough insalivation of the food is requisite. By the motion of the jaw in the act of mastication a further flow of saliva is occasioned, and this result occurs however insipid or insoluble the substance may be which is moved about in the mouth. Hence even a pebble will cause it. But if the substance possess an agreeable aroma, or a considerable degree of pungency or acrimony, a greatly augmented secretion is the consequence. In hot climates piquant articles are extensively used to stimulate the languid action of the digestive organs. [AROMATICS; FOOD.] In local affections of the mouth, nose, or even head, relief is often obtained by exciting the salivary glands to increased secretion, and this is effected by chewing pellitory root and other pungent articles, or holding in the mouth an infusion or tincture of these. Remote sialagogues are first received into the system by the stomach or other channels, and then exert a peculiar influence on the salivary glands. Of these the most familiar is mercury. This often proves highly remedial, especially in the fevers of tropical countries, in which the occurrence of salivation is always regarded as a forerunner of recovery. In persons whose systems cannot sustain mercury, or to whom it is objectionable, a deficiency of saliva, a frequent accompaniment of indigestion, is removed by the Virginian snake-root, alone, or in combination with preparations of copper.

The excessive salivation which results from even a small dose of mercury should cause the utmost caution to be observed in its use; especially as it is extremely difficult to remove it when once established, or even to mitigate its effects. [MERCURY.] But solution of chloride of soda or infusion of cloves is useful.

SIBYL (*Σίβυλλα*) is the name by which several prophetic women were designated, all of whom belong to the mythical ages of ancient history. But Pausanias (x., c. 12), who gives an account of the sibyls, applies incorrectly the same name to the female soothsayers of the historical times. (Strabo, xiv., p. 645.) It was believed that the sibyls were maidens who were directly inspired with a knowledge of the future, and of the manner in which evils might be averted, and especially of the manner in which the wrath of the gods might be appeased, and that they communicated their knowledge in inspired verses. (Varro, 'ap Lactant.,' i. 6; Cic., 'De Div.,' i. 2; Plat., 'Phædr.,' p. 244.) The number of such prophetesses appears to have been very great in ancient times, and we know of Egyptian, Hebrew, Persian, Babylonian, Greek, and Italian sibyls. Varro enumerates ten sibyls, while others only knew four. (Ælian., 'Var. Hist.,' xii. 35; comp. Suidas, *v.* *Σίβυλλα*.) Varro, however, appears in some cases to make two sibyls out of two epithets belonging to the same person, while on the other hand he does not mention the Hebrew sibyl, Sabbe. (Paus., x. 12, 5.) We shall in this article only mention the most celebrated sibyls.

The most ancient sibyl was Herophile, a daughter of Zeus and Lamia (Paus., x. 12, 1). The Erythraean sibyl was supposed to be a native of Babylonia, but some thought that she was born at Erythrae. She lived before the Trojan war, the cause and issue of which she was believed to have predicted. (Varro; Paus., x. 12, 1.) The Samian sibyl was supposed to have been a priestess in the temple of Apollo Smintheus. She spent the greater part of her life in Samos, but, like most other sibyls, she is described as travelling about and communicating to men her inspired wisdom. Thus we find her at Claros, Delos, and Delphi. She is said to have died in Troas, where a monument was erected to her in a grove sacred to Apollo Smintheus. (Paus., x. 12, 3.) Cumæ in Ionia was also celebrated for its sibyl; but the sibyl of Cumæ in Campania, called Demo, has acquired more celebrity than any other. The ancient legend about her is related by Virgil ('Æn.,' iii. 441, &c.). In the reign of Tarquinius Priscus, or, according to others, in that of Tarquinius Superbus, there appeared before the king a woman, either herself a sibyl or sent by a sibyl, who offered to the king nine books for sale. The king refused to purchase them, whereupon the woman burnt three of the books, and returning, asked for the remaining books the same price as she had asked for the nine. The king again declined purchasing; but when the woman, after burning three books more, returned and asked for the three remaining the same price which she had before asked for the nine, his curiosity was excited, and he purchased the books; whereupon the strange woman vanished. These three books were the Sibylline Books which play such a prominent part in the history of Rome: they contained the "fata urbis Romæ." (Dionys., iv., p. 259; Varro, 'ap Lactant.,' i. 6; Gellius, i. 19; Plin., 'Hist. Nat.,' xiii. 27.) Now who this sibyl was, is differently stated. Some of the ancients represent her as the Erythræan sibyl, others say that she had come from Cumæ in Ionia, and others that she was the sibyl of the Italian Cumæ. Modern writers are likewise divided in their opinions. The Sibylline Books, which were henceforth in the possession of the Roman state, are said to have been written on palm-leaves, partly in verse and partly in symbolical hieroglyphics. The public were never allowed to inspect them, but they were kept in the temple of Jupiter Capitolinus, where they were preserved in a stone chest in a subterraneous vault, and under the care of especial officers (duumviri sacrorum, interpretes, or sacerdotes sibyllæ), who had been appointed by the Tarquinius who purchased the books. These officers had to consult the Sibylline Books (adire libros sibyllinos) on all occasions when the gods manifested their wrath by inflicting calamities upon the Romans, and when human help and human wisdom were not thought capable of averting their anger. The answers which were derived from them were almost invariably of a religious nature, as they either commanded the introduction of some new worship, or the institution of new ceremonies and festivals, or the repetition of old ones. But during the time of the republic, they do not seem to have ever been used, like the Greek oracles, as a means to ascertain the future, or what political measures were to be adopted in order to attain a certain political object. The manner of consulting them, as Niebuhr and others suppose, was probably the following :—they opened the volumes at random, and whatever passage first met their eye was thought to contain the suggestions adapted for the present case. The keepers of the Sibylline Books were at first only two, with two attendants. After the banishment of the kings, the two keepers of the Sibylline Books were appointed by the people, probably in the comitia centuriata, for life. They were exempt from all civil and military offices; and whenever they had to consult the sacred books, they were authorised by a senatus consultum, and they consulted them in the presence of their attendants. The numbers of these priests was afterwards, perhaps in the year B.C. 368, increased to ten, and half of them were to be plebeians: in the time of Sulla their number was increased to fifteen.

In the year 83 B.C. the temple of Jupiter, on the Capitol, was burnt, and the Sibylline Books were consumed by the flames. In order to restore the books, the senate sent ambassadors to various towns of Italy, Greece, and Asia Minor, to collect Sibylline oracles, both from public and private sources. These ambassadors collected about one thousand verses, which were again kept in the temple of Jupiter, after it had been restored. (Dionys., iv., p. 260.) Augustus ordered that all pretended Sibylline books in the possession of private persons should be delivered up to the prætor urbanus, and burnt. On this occasion more than two thousand such books were delivered to the flames; and those oracles which were in the keeping of the state, and were considered to be genuine, were now deposited in two gilt chests in the temple of Apollo, in the basis of his statue, and entrusted, as before, to the quindecimviri. (Suet., 'Aug.,' 31; Tacit., 'Annal.,' vi. 12.) Some years afterwards, Tiberius found it necessary to institute a fresh examination of the Sibylline oracles, and to strike out many which were considered to be spurious. (Dion Cass., lvii., p. 705, Steph.) In the reign of Nero the Sibylline Books were burnt a second time, but were again restored, and used as before. In the year 270 A.D. several members of the senate advised to consult them respecting the issue of the war against the Marcomanni. (Fl. Vopisc., 'Aurel.,' 18.) About this time the Christians, in their zeal to convert the heathens, began to refer to the Sibylline oracles as containing prophecies respecting the Messiah. The collection which was in the keeping of the state was burnt a third time in the reign of Julian (A.D. 363); and a fourth time in the reign of Honorius, by Stilicho, A.D. 395. (Rut., 'Itin.,' ii. 51.) But it was restored each time; and notwithstanding all the forgeries which must have crept into it, the collection continued to be held in great esteem, as it was a useful instrument in the hands of the various parties, political as well as religious. Hence we find the Sibylline Books consulted even as late as the middle of the 6th century of our era.

A complete collection of Sibylline verses was compiled and edited by Gallæus, Amsterdam, 1689, 4to.; but it contains a great many spurious verses, and such as were made by the early Christians who pretended to be inspired. In 1817, A. Mai published a collection of fragments from the Sibylline Books, which he discovered in a manuscript of the library at Milan. Another collection of fragments was published by C. L. Struve, under the title 'Sibyllinorum Librorum Fragmenta,' Regiomont., 1818, 8vo.

SIDE. In modern mathematics this term means nothing but one of the lines which bound a figure, extending from one angle or corner to the next. The Latin word *latus*, of the same signification, is preserved in composition: thus a figure of three sides is trilateral; of four, quadrilateral; of five, quinquilateral; and so on. At the introduction of algebra, the same geometrical analogies by which a number multiplied by itself was called a *square*, procured for the number itself the name of *side;* thus 7 being the side, 49 was the square; and the same of the cube, triangular polygonal, and pyramidal numbers. [NUMBERS, APPELLATIONS OF.]

In common language the side is a vague term, implying only "part, with a notion of relative position;" it is also differently used in and out of composition. First we have the *in*side and *out*side; then, with reference to either of these, we have sides before and behind, above and below, right and left. The first pair is defined by reference to the spectator, the second by the direction of gravitation; but the third, with reference to which the term side is most frequently used, cannot be defined by the mathematician. The anatomist will say, that in the human body, the right side is that on which the heart is not, and the left side that on which it is, and there is no other definition. In every case in which the terms right and left are applied, there is a reference to the position of the human body. Thus the right wing of an army means that which is towards the right hands of those in the centre; as soon as a retreat commences, the names of the right and left wings are changed. The right bank of a river is by convention named on the supposition that the person who names it is looking down the stream, or seeing the water flow from him. Perhaps some may doubt whether the superior and inferior parts, or the anterior and posterior, are in our language properly called sides; these we must remind that the words fore-side and back-side are very good English; and that in the phrase *upside-down* we see the remains of the corresponding phrases up-side and down-side.

SIDEREAL (*sidus*, a constellation; *sideral* would be more correct), applied in astronomy to distinguish that which has reference to the fixed stars, from that which relates to the sun, moon, planets, or comets. See STAR as to general considerations, and TIME as to the distinction between solar and sidereal time.

SIEGE is the process of advancing towards a fortress under the cover of earth thrown up from trenches excavated in the ground; silencing its fire by a superior fire of artillery and musketry; and finally, by breaching the ramparts, either obliging the defenders to surrender, or forcing an entrance into the place.

A fortress is invested previously to the commencement of the siege by posting troops about it, so as suddenly to occupy all the avenues to the place, and prevent the garrison from receiving succours. The besieging army, on its arrival, establishes itself in the environs of the place at such a distance as not to be annoyed, by the fire of the artillery of the defenders; protecting itself generally by redouts raised at intervals, both on the side nearest to the fortress and on that which is towards the country. [COUNTERVALLATION.]

The operations of a regular siege, when conducted against places fortified according to any of the modern systems, are nearly the same till the approaches (the oblique lines of trenches) arrive at the foot of the glacis; and when, as in the first system of Vauban, the flanked, or most advanced, angles of the bastions and ravelins are nearly at equal distances from the centre of the place, those approaches may be directed along the produced capitals (lines imagined to bisect the angles) of a ravelin, and of the nearest bastion on each side of it; since then, when the glacis before those works is crowned by batteries, the rampart of the enceinte may be breached in two places at once. But in systems which, like that of Cormontaingne, have very salient ravelins, the approaches should be directed along the produced capitals of a bastion, and of the nearest ravelin on each side, because the glacis of the bastion cannot be crowned till the two collateral ravelins are taken; and if the lines of approach were directed as in the former case, it would be necessary to take three ravelins before either bastion could be breached. The lines of approach are carried on nearly in the direction of the produced capitals of the bastions and ravelins, because here the ground is less subject to the direct fires from the fortress.

In commencing operations, the engineers, having ascertained on the ground the prolongations of those capitals, trace, by means of pickets driven in the ground and connected by tapes, the direction of the first parallel trench, generally termed the First Parallel, A A A, which is somewhere about 600 yards distant* from the advanced parts, G G G, of the covered way. This parallel usually extends along the fronts attacked, and occasionally far enough beyond to embrace the prolongations of all the ramparts, a fire from which might be directed against the works of the besiegers: it should terminate at each extremity, if possible, in some natural obstacle, as a morass or a river; and if no such obstacle exists, a redout may be raised there, in order, by its fire, to oppose any attempt of the enemy to turn the parallel. The trench is executed by numerous working-parties of men, who, being provided with spades and pickaxes, are marched up to the ground after sunset, and are disposed along the line at intervals of four or six feet from each other. The earth obtained from the trench is thrown towards the fortress, in order to form a breastwork; and in the morning the men are relieved by others, who complete the parallel where it may have been left unfinished, and dig trenches obliquely towards the rear, for the purpose of having secure communications to and from the depôts of materials. All the trenches are sunk three feet below the surface of the ground; and the earth thrown out forming a mass about three feet high, the troops in them are effectually covered from the view of the besieged. The general breadth is 10 or 12 feet, but greater width is given in places at intervals from each other, where it may be desirable to collect troops and material.

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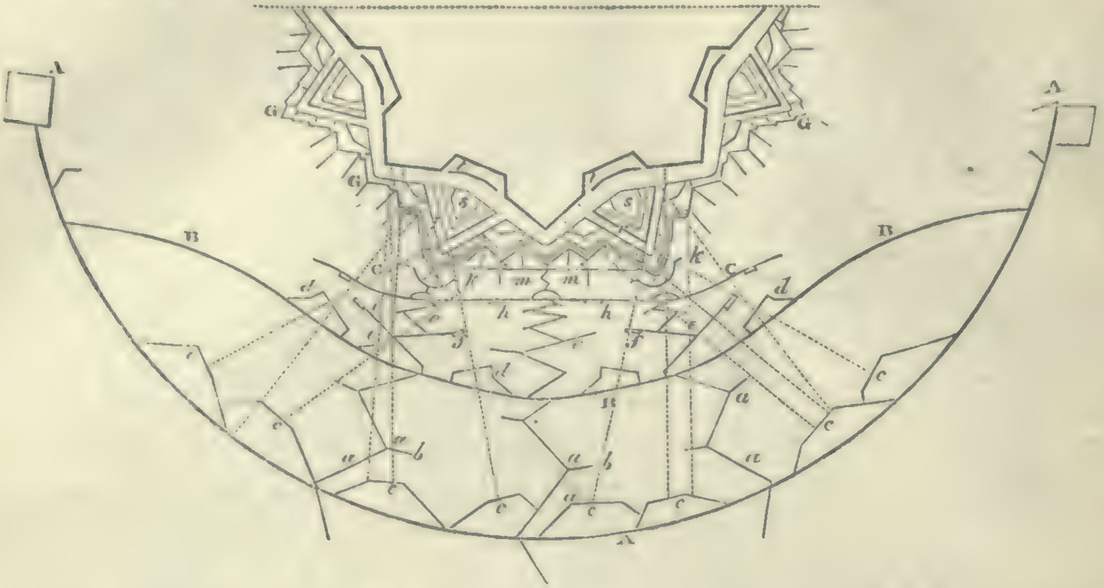
* In the present article we have taken 600 yards as the distance at which the first parallel is established, though it is very probable that in any sieges now undertaken this distance would have to be greatly increased on account of the increased range and power of the arms now in use. 600 yards was the distance generally laid down in text-books as being about the limits at which grape-shot was effective, while it would not be worth while for the garrison to expend their ammunition in firing round shot at men in such extended order, and especially at night. Now, however, unless natural cover could be obtained, it would not be possible to expose men at that distance, for the fire of musketry (rifles) would be very destructive. At the siege of Sebastopol the allies could not break ground anywhere nearer than 1200 yards, and generally from about that to 2000. The distance at which ground can be broken, however, depends so much upon circumstances, such as being screened by houses, hedges, garden-walls, &c., and the effect of the introduction of rifled arms on sieges is so doubtful, that we have retained the ordinary distance given in treatises, as by it the general principle of sieges can be easily understood; and it must be remembered that the explanation refers to a theoretic siege, in which the besiegers are supposed to greatly outnumber the besieged, and in which no disturbing circumstances, such as superior energy and courage on the part of the besieged, the failure of stores, &c., are taken into consideration. The subject is treated in the same manner that we treat abstract problems in mechanics,—disregarding friction.



The first operations of the working-parties take place during the night, in order that some progress may be made before they are discovered by the defenders; but should the latter suspect that ground is being broken, they frequently discharge light-balls, by the light of which they may discover the places where the men are at work. These places being ascertained, it may be expected that the ground will be cannonaded, or that troops will make a sortie from the fortress, for the purpose of interrupting or driving off the workmen; and in order that this intention may be frustrated, the parties are accompanied by a guard of infantry, or covering party, which is placed at about 50 yards in front of the tracing-line. These troops obtain cover if possible, or lie down on the ground, that they may not be exposed to the defenders' fire; and in the event of a sortie being made, they are ready to repel it: squadrons of cavalry are also, if the ground permits it, stationed near the extremity of the parallel, that by a rapid movement they may take in flank and cut off the retreat of the sortie.

The general uses of the parallels are to connect the lines of approach by a covered line of communication, to allow the trenches to be kept clear of troops and free for the workmen, and, affording cover and protection to the guard of the trenches and a strong position for them to remain in during the day, to serve as lines of countervallation in confining the garrison of the place. As soon as the first parallel is finished, the guard of the trenches is moved into it, for the purpose of protecting the succeeding operations. While the approaches are being pushed forward, or indeed while the first parallel is being completed, the batteries C, C, C...., are formed either in or in advance of the first parallel to keep down the fire of the place either by direct or enfilade fire as shown by the dotted lines.

Since the trenches leading from the first parallel towards the place ought not to be enfiladed from thence, it is evident that they must be formed in zig-zag or oblique directions *a a a*, &c., crossing and recrossing the produced capitals of the bastions or ravelins; and that the several branches, if produced, should fall on the exterior of all the works of the place. The first oblique *boyeau* (branch) of the trench may be defended by the fire of the parallel; but the second may, if found necessary, be protected by the fire of troops stationed in a small trench, *a b*, called a parallel boyeau, at the angle between the first and second branches; and a short branch for the like purpose is generally formed at the angles of all the zig-zag trenches. If the directions of the several oblique branches are not laid down on the ground, from a plan of the intended operations previously made on paper, the engineer endeavours, during the daylight, to observe, in the direction of the most advanced part of the glacis towards his right or left hand, some object towards which the tracing-line may be stretched and the trench carried on. These trenches are then executed by the working-parties, in the same manner as the great parallel was formed. At the siege of Badajos, in 1812, a French corporal, in the dusk of an evening, dexterously displaced a tracing-line, which had been stretched by the British engineers, and directed it so that the trench executed along it might have been enfiladed by three guns on the ramparts of the castle. If the derangement had not been discovered before darkness came on, the labour of the whole night would have been lost, and casualties might have occurred from the fire which the garrison might have directed along the trench. The workmen are usually relieved after it is dark, in order that the change may not be observed from the fortress; but the officers should be relieved earlier, that those who come on duty may have light enough to examine the actual state of the works, and to take measures for directing the operations of the men during the night.

When the heads of the trenches have arrived within 300 yards of the covered-way, which is usually about the fourth night from the time of opening the trenches, a second parallel, B B B, is formed, in order to facilitate the communication between the several lines of approach, and to protect the working-parties, for it is evident that having got half way between the first parallel and the place, as the boyeaux advance the working-parties in them are nearer to the enemy than to their supports. This trench may be extended along the particular points attacked, and its extremities may be terminated by redouts, or continued till they fall into the first parallel. It is executed by flying sap [SAP], that the men may be quickly protected from the fire of musketry in the covered-way, which might now begin to take effect.* One of the principal means of accelerating the surrender of the fortress is that of enfilading the ramparts, in order to dismount the guns and drive the defenders from the parapets. But in order to be effective, the range for ricochet fire should be short; for this reason fresh batteries, *d d d*, &c., are raised in the directions of the produced faces of the works, in or near the second parallel, which thus may form a secure communication between them, and are armed with guns moved up from the first parallel. [BATTERY; RICOCHET.] From the same batteries also an oblique fire may sometimes be directed against the interior of the flanks and curtains, and a plunging fire into the ditches, in order to impede the communication between the place and the outworks. All the different ricochet batteries commence firing at the same time, that the attention of the defenders may be divided, and that they may be prevented from concentrating all their fire upon one battery; the guns also should be fired singly, and at intervals so regulated that there may be always some shot or shells in the air, for thus the enemy will have little time to repair the damage done to his artillery or to the parapets. The firing should be commenced during daylight, in order that the artillerymen may be able to determine by trial the charge of powder and the degree of elevation for each piece, so that the shot may just clear the parapet of the work to be enfiladed; this being obtained, the direction of the piece may be preserved by means of timbers nailed to the platform, and thus the fire may be kept up with equal accuracy by night and by day.

After the fire from the ricochet batteries has partly silenced that of the place, the trenches of communication are continued in zig-zag directions as before, and with the like precautions against being enfiladed from the fortress and its covered way. These and all the succeeding trenches may be executed by full sap [SAP], while the fire of the besieged continues in activity; but if that fire should become at any time relaxed, the opportunity may be seized of carrying on some part of the approaches in a more expeditious manner. When the heads of the oblique trenches are about half-way between the second parallel and the foot of the glacis, a demi-parallel, *e e*, &c., is carried out on each side of the produced capitals of the works attacked, till it meets the prolongation of the crest of the covered-way: its use is to protect the works which are to be executed in its front by a fire of musketry, which, being nearer, is more effectual than that of the second parallel. Howitzer batteries, *ff*, &c., are formed at the extremities of these parallels for the purpose of enfilading the covered-way with shells, and thus destroying the palisades and traverses. As soon as the fires from the howitzers have produced some effect, the oblique trenches may be continued till they arrive at the foot of the glacis, on the capital of each of the works attacked, the branches being directed, as before, towards the exterior of any part of the covered-way from whence the enemy might enfilade them; and each being prolonged towards the rear about 10 or 12 yards, in order to form places where tools and materials may be deposited out of the line of passage along the trenches. If the defenders should have established redans or redouts at the foot of the glacis, or should have carried out counter-approaches from any of the collateral works, in order to enfilade the trenches of attack, they must be assaulted and destroyed as soon as it is found that the fire from thence impedes the operations of the besiegers.

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* It must be understood that this refers to smooth-bored fire-arms.

A third parallel trench, C C, may now be executed to connect the points of attack at the foot of the glacis; for this purpose the squads of sappers turn to the right and left from the head of each line of approach, and meet each other, forming as they proceed a trench which is either rectilinear or curved towards the re-entering parts of the fortress, in order to enable the troops in it to fire less obliquely on the branches of the covered-way. This parallel should be made broader than the others, because considerable bodies of troops are occasionally collected in it, and at intervals steps should be made in it long enough to allow a company of men to mount in line over the parapet. For the protection of the troops, the crest of its parapet should be furnished with sand-bags disposed so as to leave between them small intervals (loop-holes) to fire through; and in this parallel, batteries, *h h*, &c., for small mortars may be formed, in order that shells may be thrown from thence into the principal works. It is estimated that the third parallel may be finished by about the tenth night from the time of opening the trenches.

At this period, should any great necessity exist for hastening the surrender of the place, should also the garrison be weak, and should there be no retrenchments in the covered-way, it may be thought proper by main force to assault the latter, and immediately crown the glacis with batteries for breaching the works. In this case, the defenders should be driven as much as possible from the covered-way by a heavy fire from the mortar and howitzer batteries; then the troops who are to make the assault, having been assembled in the third parallel, mount, at a signal a little before sun-set, over its parapet, and proceed rapidly up the glacis. A party of men then extend themselves along its crest, and by their fire keep down that of the defenders on the parapets; in the meantime the sappers commence forming with gabions a lodgment on the crest, and the rest of the storming party endeavour to force an entrance through breaches made by artillery in the palisades. When the defenders have thus been compelled to retire behind the traverses in the covered-way, the assailants, who then become exposed to the fire from the parapets of the bastions or ravelins, retire into the lodgment which by this time may be finished on the crest of the glacis; and during the night there may be executed trenches of communication from the lodgments to the third parallel. The lodgments thus formed may be afterwards connected together, and extended to the right and left if necessary; and in these the breaching batteries may be formed.

Should the fortress have small ravelins, like those of Vauban, the assault may take place at once on the salients of a ravelin and of the two collateral bastions; but if the ravelins advance far towards the country, as in Cormontaingne's system, it can take place only at the salients of the ravelin on each side of one bastion; since if it were attempted to carry on the approaches between the two ravelins, the troops and sappers would become exposed to fires on their flanks and in rear as well as in front.

An assault [ATTACK] by main force is always attended with considerable loss, and therefore, if time permits, it is preferred to continue carrying on the approaches by sap. For this purpose, supposing the place to be fortified with large ravelins (as in the cut), a trench is begun at about 30 yards on each side of the ridge between the two faces of the glacis before the ravelins only, and carried in a curvilinear direction till the two squads of sappers meet on the ridge about eight or nine yards in advance of the third parallel. From hence the trench is continued by double and direct sap along the ridge till it arrives at between 30 and 40 yards from the crest at the angle of the glacis; and at this spot, formerly, high breastworks, called trench cavaliers, *k k*, &c., about the thirteenth night from the time of opening the trenches, were raised on the prolongations of the branches of the covered-way, in order to allow a plunging fire of musketry to be directed into those branches. But as the fire of the defenders' artillery may prevent the construction of such works, instead of them there are now formed batteries armed with small mortars from which balls or stones may be projected into the covered-way in order to compel the defenders to retire from thence. (Mortars for throwing stones are called by the French *pierriers*.)

After the fire from the cavaliers or mortar-batteries has obliged the enemy to abandon the advanced parts of the covered-way, double saps are carried on towards the salient angle of the glacis, and when they have arrived at about 24 feet from that angle, the crowning of the glacis commences. This is performed by extending the sap along the crest on each side of the angle, and throwing up the earth towards the place in order to form epaulements for batteries. That the crowning trenches may be secured against the enfilading fires from the collateral works of the besieged, traverses are formed across them at intervals in situations where they may not interfere with the guns to be placed in the batteries; and, on account of the fire which the enemy may still keep up from the branches of the covered-way and the retrenchments in the re-entering places of arms (see the figure in art. FORTIFICATION), a portion of a fourth parallel, *m m*, should now be carried out in order that troops placed there may protect the sappers during the formation of the batteries, and the artillerymen during the operation of breaching the ravelins. The crowning of the glacis is sometimes extended along the faces of the re-entering places of arms; and in this case trenches on those faces are connected with the fourth parallel by lines of communication formed in serpentine directions.

The epaulements raised by the besiegers between the salient angle of the glacis and the first traverses on each side are to serve as counter-batteries, whose use is to ruin the parapet and dismount the guns in the faces or flanks of the collateral works, in order as much as possible to prevent the enemy from opposing by musketry or artillery the passage which is to be effected across the ditch; and the epaulements between the first traverses and the re-entering places of arms serve for the breaching batteries. [BREACH.] The crowning batteries on the glacis of two ravelins, *r r*, are supposed to be finished about the sixteenth night from the time of opening the trenches.

While the breaches are being formed, the passages by which the descents into the ditches of the ravelins are to take place are commenced. These are either open trenches or subterranean galleries cut in inclined planes through or under the covered-way opposite the breaches; each passage thus terminates at a perforation in the counterscarp about 3 feet above the bottom of the ditch if dry, or at the level of the water if it contain any. The sappers throw fascines into the ditch if dry, till the heap is sufficiently high and thick to secure them from the fire of the defenders, and then getting in, they form by sap a trench and parapet extending some way up the breach itself. Preparations are afterwards made for the assault.

For this purpose the interior of the batteries and the passages leading to the ditches are during the night filled with troops, in whose rear are bodies of sappers with their materials; and early in the morning, after a heavy fire has been for some time kept up from the batteries in order to drive off the defenders, the troops charge up, and endeavour to keep the enemy engaged while the sappers execute lodgments on the breaches by filling their gabions with the loose earth; as soon as these are finished, the storming parties retire behind them, and from thence keep up a fire upon the enemy. These lodgments should if possible be on the tops of the breaches, but if the interior of the ravelin is retrenched by a redout, as *s s*, whose fire commands those spots, the lodgments must be formed on the ascent, that they may not be immediately destroyed. It is estimated that the two ravelins may be taken about the eighteenth night.

If the ditches contain water which cannot be made to flow off, there may be formed across them solid causeways consisting of fascines laden with stones to make them sink, or of casks or gabions having their axes in horizontal positions; or floating-bridges of timber-logs, casks or pontoons may be constructed; and by any of these means the troops may pass over to the assault. From the lodgments just mentioned trenches are carried on by sap directly to the top of the breach, and from thence turning to the right and left they are continued about half-way down the faces of the ravelins: their extremities being made to join the parapets of these works.

The redouts in the two ravelins are next to be taken; and to effect this object, it being supposed that the faces of the ravelins are too narrow to allow room for forming batteries on them, either a portion of the ravelin must be blown up in order to allow the fire of the breaching-batteries on the glacis to act against the redouts through the apertures, or else the redouts must be breached by undermining them. Should the latter method be preferred, a trench or gallery is cut through the mass of each ravelin, and a sap is carried across the ditch of the redout; the miner then, being secured against the effect of the enemy's grenades by timbers placed in inclined positions leaning against the scarp of the redout, cuts through that scarp and forms chambers for the reception of gunpowder. This being fired, a part of the rampart will be destroyed and a breach formed. An assault is then made by troops, and the defenders being supposed to be driven out of the works, a battery may be raised along the gorge of each redout in order to compel them to quit the tenailles, *t t*, in the main ditch. The redouts of the ravelins being taken (probably about the twenty-first night), the defenders will also be obliged to retire from the rear extremities of the latter works; and the besiegers occupying those extremities, their fire from thence commanding the interiors of the redouts in the re-entering places of arms, these last must also be abandoned.

The approaches towards the bastions may now be recommenced, as the fires from the ravelins are no longer to be apprehended; therefore a double sap is carried on from the curved trench in the third parallel directly along the ridge of the glacis, till it begins to be plunged into by the fire from the bastion: it then proceeds in a serpentine direction till its head arrives between the portions of the fourth parallel already formed. This parallel is then completed, and under the protection of the fire from the troops stationed in it, the counter and breaching batteries before the bastion are formed. By the former the fire from the guns in the flanks of the collateral bastions is partly silenced, and by the latter the breach in the faces of the opposite bastion is effected. The passage through the counterscarp and a trench across the main ditch are then executed, and an assault may be made up the breach of the bastion, similar to those which had been made up breaches of the ravelins; the defenders being repelled, a lodgment may be formed, and unless the bastion is strongly retrenched, it may be expected that the place will now be surrendered. It is estimated that the assault of the bastion may take place about the twenty-sixth night from the time of opening the trenches; but a good retrenchment [RETRENCHMENT] in a bastion may enable the defenders to hold out ten or twelve days longer.

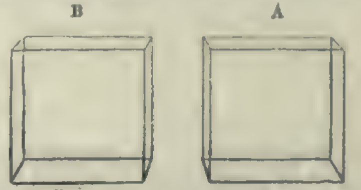
A fortress is said to be countermined when subterranean galleries are formed under the ramparts of the bastions and ravelins; under the covered-way, and under the ground at the foot of the glacis, with galleries of communication from one of these to another. And as the defenders can form chambers and place powder in or near any convenient parts of these galleries to destroy the works of the besiegers above-ground, the besiegers find themselves under the necessity of sinking shafts and forming galleries for the purpose of finding out and destroying those of the defenders, or of blowing up any of their advanced works. [MINES, MILITARY.]

A siege conducted according to the rules of art will be attended with comparatively small loss to the besiegers or besieged, the troops of both parties being but little exposed to each other's fire except at the times when the assaults are made on the ravelins or bastions. And if circumstances, such as the prospect of the place being relieved, did not compel the besiegers to expedite the surrender, the assaults by main force might be avoided; for after a breach has been formed, and the parapets of the place have been in a great measure ruined by the artillery of the besiegers, a sapper might be sent across the ditch by night with instructions to commence a trench under cover of one extremity of the broken wall; then, if he succeed in getting cover for himself, others may follow, and gradually there may be formed on the breach a lodgment sufficiently large to contain troops, whose fire would protect the succeeding operations: it being understood that a firing party in the batteries on the glacis force the defenders to retire as often as they endeavour to disturb the sappers while at work.

The want of time and means to carry on the approaches as far as the covered-ways was the cause of the great losses sustained in getting possession of the fortresses garrisoned by the French in Spain during the Peninsular war. The breaches in the walls of Badajos (1812) were made by guns in batteries at the distance of 500 yards; and when the assailing troops had descended into the ditch, being ignorant of the positions of the breaches, and confused by the darkness of the night, which was relieved only by the appalling and destructive blaze of live shells and other combustibles thrown upon them from the parapets, they took a wrong direction, or remained patiently to be slaughtered till the order was given to retire. The effort would have entirely failed, but for the success of Major-General Picton in escalading the walls of the castle, and of General Walker in escalading the bastion of S. Vincente.

SIGHT (vision, the faculty of seeing). The structure and uses of the several component parts which enter into the formation of the organ of vision have been already described in the article EYE, in NAT. HIST. DIV. We have now to inquire by what means the images of objects which are depicted on the retina become converted into ideas of the objects themselves; of their proximity and distance; of their solidity and size. In other words, is the interpretation of the sensations of the retina a vital property of the structure itself, or is it in part derived from other sources? The following case, which is recorded by Cheselden, affords us important data on this head. A young man, who was born blind, was suddenly restored to sight by the operation of couching. "When he first saw," observes Cheselden, "he was so far from making any judgment about distances, that he thought all objects whatever touched his eye (as he expressed it), as what he felt touched his skin. He knew not one thing from another, however different in shape and magnitude; but upon being told what things were whose form he before knew from feeling, he would carefully observe, that he might know them again. Two months after being couched, his attention seems to have been drawn to the effects of painting, which he then first and at once comprehended; but even then he was no less surprised, expecting the pictures would feel like the things they represented, and was amazed when he found those parts which by their light and shadow appeared round and uneven, felt only flat like the rest, and asked which was the lying sense, feeling or seeing? Being shown a small miniature of his father, and told what it was, he acknowledged a likeness, but was vastly surprised, asking how it could be that a large face could be expressed in so little room, saying it should have seemed as impossible to him as to put a bushel into a pint. At first he could bear but very little light, and the things he saw he thought extremely large, but upon seeing things larger, those first seen he conceived less, never being able to imagine any lines beyond the bounds he saw. The room he was in, he said he knew to be but part of the house, yet he could not conceive that the whole house could look bigger." From the details of this interesting case, it would appear that the sense of sight (so far as we can judge of it when performed with one eye, for only one had been operated on when the above phenomena were observed) originally gives us no information respecting the solidity, the distance, or the real magnitude of objects; but that they all seem as if painted on one surface. If this then is the sum of the information which is conveyed to us by the retina; if it is limited to the mere perceptions of the images of objects, and conveys to us ideas relative to superficial extent only, it is clear that our estimation of the true position, the magnitude, and solid forms of bodies must be due to some other sense than that of sight, or rather, to a comparison of some other sense with it; in short, to an act of our comparing and reasoning faculties.

We have seen by the details of the above quoted case, that there is no essential resemblance between the ideas which are derived from vision and those communicated by touch; and it is no doubt partly owing to this circumstance that we obtain a correct knowledge of external objects through our visual organs. The lad couched by Cheselden could not recognise by sight the things whose form he before knew from feeling; but upon being told what they were, he would carefully observe, that he might know them again. The infant, in like manner, stretches out its little hands to grasp and examine each object in succession which attracts its sight, and the greater part of its waking hours is employed in thus comparing the sensations obtained through these two different channels. That we do acquire important information respecting the size and forms of bodies through the sense of touch there can be no doubt; that the knowledge obtained through our visual organs would be imperfect without it, and that it may in some measure be a corrective of those optical illusions which are so frequent when we attempt to judge of things by sight alone, is equally probable; but in admitting this, we must not underrate the original powers of the eye and the quantity of knowledge which we primarily derive from it. From some facts we are about to notice, it would appear that much of the information which we derive from our visual organs only, has hitherto been attributed to extraneous sources. Physiologists have been too much swayed by the opinion of Gassendus, Haller, Gall, and others, that we see with only one eye at a time, and those even who disputed this have been more anxious to explain why objects are seen single with both eyes than to inquire into the uses of our possessing two. These defects, which are more or less common to all writers on optics, have been some years since remedied by some very interesting observations of Professor Wheatstone on Binocular Vision. He has shown that the simultaneous affection of the two retinæ, provided the optic axes are not parallel, excites a different idea in the mind from that consequent on either of the single impressions; the latter giving rise to a representation on a plane surface, the former to that of an object in relief. This is owing to a different perspective projection of the object being seen by each eye; thus, if any figure of three dimensions, an outline cube for example, is held at the distance of about seven inches before the eyes, and viewed with each eye successively while the head is kept perfectly steady, A will be the picture presented to the right eye, and B that seen by the left. Now if these two pictures are made to fall on corresponding parts of the retinæ, by placing them one in the direction of each optic axis at equal distances before or behind their intersection, the mind will perceive not merely a single representation of the object, but a body projecting in relief, the exact counterpart of that from which the drawings were made.

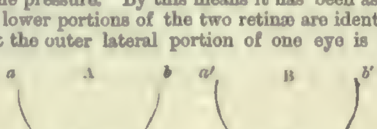


But a better method is to employ the stereoscope, an instrument invented for the purpose by Mr. Wheatstone, the essential parts of which are two plain mirrors inclined with their backs towards each other at an angle of 90°. The two pictures A and B are placed in the same horizontal line, and parallel to each other at the sides of these mirrors, and at equal distances from them. The observer then placing his eyes as near as possible to the two mirrors, their angle coinciding with the middle line of his forehead and face, sees the solid body represented by the perspective drawings standing forward in relief, provided the two drawings are so situated that their images reflected by the mirrors coincide with the lines of the convergent optic axes. Instead of the original reflecting stereoscope of Mr. Wheatstone, an instrument of the refracting form introduced by Sir David Brewster, and now so common, may be used in the experiment. When similar images, differing to a certain extent in magnitude, are presented, by means of the stereoscope, to corresponding parts of the two retinæ, a single object, intermediate in size between the two monocular pictures, is seen. Were it not for this, objects would be seen single only when the optic axes converge directly forwards; that is to say, when the object is equally distant from the two eyes; for it is only then that the images on the retinæ can be of equal size, the size of the image being dependent on the angle under which the object is seen, and this being less as the object is more distant. As our conviction then of the solidity and projection in relief of bodies depends upon a different perspective image of them being presented to each retina, and as this can only take place when the axes of the eyes are made to converge to them, it follows that when objects are at such a distance that in regarding them the optic axes are parallel, their images on the retinæ will be exactly similar, and the idea conveyed to the mind will be the same as if they were seen with one eye only. Hence, when two perfectly similar pictures of an object are viewed in the stereoscope, although they coalesce, they appear but as painted on a flat surface. With a knowledge of these facts, it becomes easy to explain why the artist is unable to give a faithful representation of any near solid object, that is, to produce a painting which shall not be distinguished in the mind from the object itself. When the painting and the object are seen with both eyes, in the case of the painting two similar pictures are projected on the retinæ; in the case of the solid object the pictures are dissimilar; there is therefore an essential difference between the impressions on the organ of sensation in the two cases, and consequently between the perceptions formed in the mind; the painting therefore cannot be confounded with the solid object. As our belief then in the solidity of a near object is owing to our taking cognisance of the impressions on both retinæ, it is interesting to inquire whether any other kind of information is imparted to us by the possession of two eyes, which we should not obtain by one only. It is well known that if we close one eye, and attempt to judge of distances with the eye that remains open, our conjectures are wide of the mark, and the rationale of this has been explained by Le Cat, in his 'Traité des Sensations,' in the following words:—"The concurrence of the optic axes, and the length of the angle they form, are the fundamental principles for estimating the distance of objects: hence it is that when we look with one eye only, we are unable to distinguish distances, and cannot place the end of the finger directly upon an object indicated to us, though it be very near, for the finger hides the object, and appears to correspond to it as exactly when it is at the distance of a foot, as if it were only a line removed from it. But if our other eye be open, it will see the finger and the object from the side, and will therefore discover a considerable interval between them if they are a foot distant from each other, but only a very small interval if they are very near; and thus we are enabled to place our finger with certainty upon the desired object."

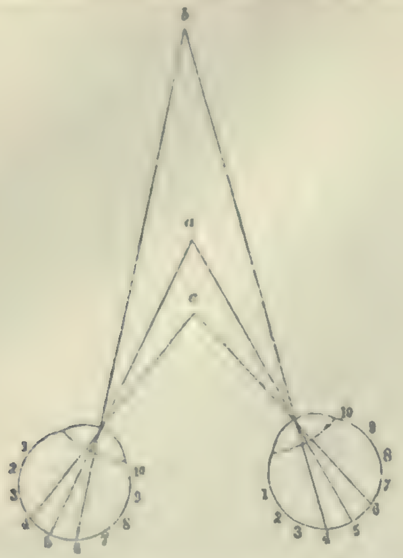
The convergence of the optic axes which takes place when we regard objects within a short distance of us, is supposed by many to assist us in our judgment of the magnitude of bodies, and if this is admitted, it is another proof of the variety and extent of information conveyed to the mind by the possession of two eyes, which a single eye could only have afforded with the aid of the movements of the head and of the sense of touch. The confusion of vision and the indetermination of judgment which follow the loss of an eye, often continue for many months, and strikingly illustrate the truth of the foregoing remarks. Our estimation of the distance and size of remote objects is purely a matter of experience; an object appears distant in proportion to its indistinctness of colour and outline, to the number of intermediate bodies seen between it and the observer, and to its appearing relatively smaller than these. We judge of the magnitude of objects by a calculation founded on their apparent size and probable distance: hence we are liable to continual mistakes on these points. An Englishman in the clear atmosphere of Italy supposes distant objects to be nearer to him than they are. A mountain which we see at a distance for the first time appears generally much less than it really is, and we think it near us when it is very far away. From these remarks it is evident that the mind is constantly co-operating in the acts of vision, so that it becomes difficult to say what belongs to mere sensation, and what to the influence of the mind: that the latter must take an active part in the conceptions of vision, is evident from the great difference in the extent of the actual and the mental field of vision. The one is dependent on the extent of the retina; the other has no determinate limits: in one, all objects are of equal magnitude that are seen under the same angle, and therefore produce an image of the same size upon the retina; in the other, the images of these objects though viewed under the same angle, are of various sizes and placed at very different distances.

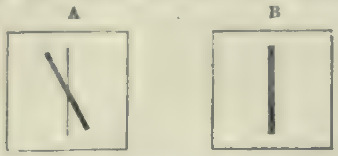
It is scarcely necessary to say much in reference to the movement of bodies: we judge of their motion partly from the movement of their images over the surface of the retina, and partly from the movement of our eyes following them. If the image upon the retina moves while our eyes and body are at rest, we conclude that the object is changing its relative position with regard to ourselves. In such a case the movement of the object may be apparent only, as when we are fixed upon a body which is in motion, such as a ship. On the other hand, the image may remain fixed on the same spot of the retina, while our eyes follow the moving body; we then judge of its motion by the sensations in the muscles which move the eyes. If the image moves only in correspondence with the actions of the muscles, as in reading, we infer that the object is stationary. The sensations of rotatory movements of objects, produced by turning the body on its axis, are quite independent of any impressions on the retina, and their consideration is therefore foreign to the subject we are treating of. The apparent movement of objects after looking at those really moving, may arise from the successive disappearance of spectra left by the moving bodies. From the fact that artificial excitement of the retina, either by pressure, electricity, or any other cause, gives rise to the perception of colour as well as light, we infer that the retina is the seat of these sensations. The colour of luminous bodies depends upon the quality of the light they emit; the colour of bodies that are not luminous is due to the light which falls upon them, and is reflected by them towards our eyes. When a body absorbs all the rays of light which fall upon it, its colour is black; when it reflects them all, it is white; and when it absorbs some and reflects others, it is coloured. [ABSORPTION.] The question has often been raised, why is it that we see objects erect, while their images on the retina are inverted? According to most physiologists, it is by virtue of a certain property of the retina by which each point of an object is seen in the direction of a line perpendicular to its surface; now since this surface is concave, the rays proceeding from an object which fall on the lower part of its concavity will incline upwards, while those which impinge on its upper part will incline downwards; and thus the object presented to the mind will be the reverse of that which is depicted on the retina. Many physiologists reject this theory, on the ground that it involves an impossibility, since each point of the image is not formed by rays having one determinate direction, but by an entire cone of rays; they affirm moreover that vision can consist only in the perception of the state of the retina itself, and not of anything lying in front of it in the external world. They argue further, that no explanation of erect vision is required, as long as all things equally, and not some objects only, appeared to the eye inverted; for nothing can be inverted where nothing is erect, each idea existing only in antithesis to the other. A question not less agitated than the one we have just discussed, is that of single vision with both eyes. We shall not inquire into the merits of the various theories that have been invented in order to account for this phenomenon; but shall merely advert to the principal conditions which are essential to single vision, in order that we may explain under what circumstances double vision results.

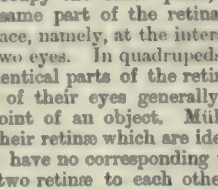
If two fingers are held up before the eyes, one in front of the other, and vision is directed to the more distant, the nearer will appear double, while if the nearer one is regarded more particularly, so as to appear single, the more distant will be seen double, and one of the double images in each case will be found to belong to one eye, and the other to the other eye. This phenomenon has given rise to the hypothesis that there are certain corresponding or identical points on the two retinæ, and that when these are affected simultaneously, single vision results; while if the image of an object falls on parts which are not identical, it is seen double. A knowledge of these facts is obtained in the following manner:—If in a dark room with our eyes closed we make pressure with the finger upon any part of the ball of the eye, so as to affect the retina, a luminous circle will be seen in the field of vision at the opposite side to that on which the pressure is made. If we press on both eyes simultaneously, *one* luminous ring is seen when "identical" parts are pressed on, and *two* rings when "non-identical" parts receive the pressure. By this means it has been ascertained that the upper and lower portions of the two retinæ are identical with each other, and that the outer lateral portion of one eye is identical with the inner portion of the other, and so of the intermediate parts. Now whenever the axes of our eyes converge to an object, its image falls on corresponding portions of the two retinæ, and is seen single; when we regard it without making our optic axes meet in it, as in the experiment of holding up two fingers, non-identical parts of the retinæ are affected, and it is seen double. To illustrate this, let *a* be a point towards which the axes of the eyes are directed, and *b* an object more distant from the eyes. An image of *a* will fall upon identical points of the two retinæ, namely, upon the central points 5, 5; *a* will consequently be seen single. The image of *b* will fall in the left eye at 6, and in the right eye at 4. The points 4 and 6 of the two eyes being non-identical (since the identical parts are marked with corresponding figures), *b* will be seen double; and the distance between the two images of *b*, in proportion to the extent of the whole field of vision, will be the same as that between 4 and 6, in comparison with the distance between 1 and 10 in each retina. The centre of the retina furnishes the most distinct vision, therefore double images, which generally fall on the lateral parts, are indistinct. The position of double images depends upon the point at which the axes of the eyes decussate; if in front of the object, the left hand image belongs to the left eye, and the right hand image to the right eye; while if the axes converge to a point beyond it, the converse of this is observed. That objects will not in general be seen single, unless their images fall on corresponding portions of the two retinæ, is further confirmed by the phenomena which are observed in strabismus, and by the experiment of displacing the axis of one eye by



pressing on it with the finger; but that exactly identical points of the retinæ must be affected by similar points of the two images, is sufficiently refuted by Mr. Wheatstone's discovery of different perspective projections being presented to each eye. Mr. Wheatstone has also shown that under some circumstances similar pictures falling on corresponding points of the retinæ may appear double and in different places. If to one eye we present in the stereoscope a vertical line B, to the other eye a line inclined some degrees from the perpendicular, we shall see a line the extremities of which appear at different distances before the eyes. If now we draw a faint vertical line, intersecting the inclined line at its centre, as at A, and present the two drawings to the eyes as before; the two strong lines will still coincide, and the resultant perspective line will occupy the same place, while the faint line, though it occupies the same part of the retina as the vertical line B, appears in a different place, namely, at the intersection of the planes of visual direction of the two eyes. In quadrupeds the relation between the identical and non-identical parts of the retinæ cannot be the same as in man, for the axes of their eyes generally diverge and cannot be made to meet in one point of an object. Müller therefore supposes that there are parts of their retinæ which are identical, and parts which are not identical, which have no corresponding parts in the other eye, and the relation of the two retinæ to each other in the field of vision may be represented as below. Although the theory of corresponding points is the most perfect that has yet been offered in explanation of the phenomena of single and double vision, yet the facts which have been advanced against it by Mr. Wheatstone are sufficient to show that it cannot be adopted without some limitation. Were it even not liable to these objections, it would still only express the *conditions* required for single and double vision, and would leave unexplained the *cause* of two impressions giving rise to one sensation.







There are several curious phenomena connected with the subject we are treating of, some of which we will briefly allude to. If a piece of white paper is viewed through two different coloured glasses, held one to each eye (for instance, through a blue and a yellow glass), the paper is not seen of a green colour, or rather of the whitish colour which would result from the strict mixture of the two colours, but in part blue and in part yellow. Sometimes one colour predominates, sometimes the other; and if the experiment is long continued, the mingling of the colours, to which there was at first no tendency, becomes more evident. Similar phenomena are observed when two dissimilar pictures are viewed in the stereoscope, and it does not appear to be in the power of the will to determine the appearance of either picture or either colour. These facts seem to show that the two eyes are not always in action together; but that at one time the sensations of one eye predominate, and at another those of the other. If the eyes are closed after being fixed for some time on an object, we still continue to see its image, and the duration of this image, or "spectrum," as it is called, is in a direct ratio with the impression which caused it.

Spectra left by the images of white or luminous objects are ordinarily white or luminous, and those left by dark objects dark; but if, instead of closing the eyes, they are directed upon some white surface, as a sheet of paper, the colours of the spectra are reversed, those which were white when the eyes were closed becoming black when directed to the white surface, and *vice versâ*. These phenomena are easily explained. The part of the retina which has received the luminous image remains for some time afterwards in an excited state, while that which has received a dark image is in an unexcited and therefore much more excitable condition. When the eye in this condition is directed towards a white surface, the luminous rays from this surface produce upon the excited parts of the retina a much more feeble impression than upon the unexcited, and the latter consequently appear more illuminated. Spectra are sometimes coloured, although the objects which excited them are colourless; such is the case if the impressions on the retina are very intense, as when produced by the sun's image. But the most curious phenomena relative to ocular spectra arise from the impression of coloured objects on the retina; the spectra consequent on these, although coloured, are not of the same colour as the object, but the opposite or complementary colour. Thus the spectrum of a red object is green, that of a green object red, that of a violet yellow, &c. There are two modes of explaining these phenomena, the least objectionable of which is the following, offered by Muller: "The perception of any one of the three simple colours consists merely in the retina being in one of those conditions to which it has a tendency when in a state of excitement; if this condition be artificially excited in an intense degree, the retina acquires an extreme tendency to that of the complementary colour, which consequently is perceived as the ocular spectrum."

The disappearance of images which fall on the retina at the entrance of the optic nerve, the luminous circles seen on making pressure with the finger on the globe of the eye, and the vascular network which, under certain circumstances, we perceive in our own retina, have already been alluded to and their causes explained in the article EYE, in NAT. HIST. DIV.

SIGHT, DEFECTS OF. Under this head will be comprehended short-sight, long-sight, double vision, and the defective perception of colours, or colour blindness.

Myopia, or *Near-sightedness* (from μύω, "I shut," and ὤψ, "the eye," a short-sighted person being in the habit of winking, or half shutting his eyelids when he endeavours to see objects distinctly).

When the images of surrounding objects are brought to a focus in the eye before they reach the retina, such an eye is myopic; when, on the contrary, their foci would fall behind the retina, it is presbyopic. Individuals thus affected see all objects indistinctly that are viewed at the ordinary distance of distinct vision; therefore, to remedy this defect, they bring them within such a distance of the eye as will ensure their images being brought to an exact focus upon the retina. The point of distinct vision (that is, the distance from the eye at which objects are perceived most clearly) of a perfect eye averages from 15 to 20 inches: an eye which cannot discern objects distinctly beyond 10 inches may be considered myopic; but persons affected with a high degree of myopia have their point of distinct vision as near as two or three inches, or even one inch, to the eye. To short-sighted persons all objects appear magnified; they prefer to read a small type, and see better through a pin-hole in a card than with the naked eye: on the same principle, when they endeavour to see any distant object distinctly, they almost close their eyelids. The explanation of these phenomena is to be sought for in the condition of the eyes themselves; they are generally firmer than usual, their corneæ are preternaturally convex, and their pupils large; hence by diminishing the aperture through which the light is admitted, all but the more direct rays are excluded, and the images on the retina will be more defined.

The cause of myopia is an over-refractive condition of the eye; either the cornea or the crystalline lens is too convex, or the humours of the eye generally are too dense or too abundant.

Treatment.—Although it is said that short-sightedness rarely comes on before puberty, our own observations lead us to believe that it is more frequently a congenital defect than is generally imagined. If, however, an incipient case were brought under the notice of the practitioner which could be shown to have followed too great an exercise of the eyes upon minute objects, the cure would probably be found in abstaining entirely for a time from such occupations, refraining also from the use of convex glasses, and employing the eyes chiefly upon large and distant objects. But this defect is one that is so little thought of, and is so easily remedied by the use of glasses, that a medical man is seldom called upon to attempt its cure: the only plausible means that have been recommended with this view are, practising the eyes in reading at gradually increasing distances, and a renunciation of such pursuits as require the concentration of vision upon near objects. The manner in which concave glasses improve the vision of near-sighted persons, is by causing a divergence of the rays of light before they enter the eye, thus counteracting the over-refractive condition of that organ. The glasses that are most commonly used are double concaves, of equal concavity on each side; they are numbered 1, 2, 3, 4, &c., beginning with the longest focus or shallowest concavity. Unfortunately there is no uniform standard adopted in the manufacture of these glasses, so that what one optician calls No. 1, another rates as No. 2, and so on; it is therefore advisable that those who wish to fit themselves with spectacles should try a series of them at an optician's shop, and they should be content with the lowest number with which they can see objects clearly across the street; if it diminishes them much, or gives them a dazzling appearance, or if the eyes feel strained after looking through them for a short time, they are too concave. Spectacles are always preferable to a single eyeglass; and when the individual has met with a pair which suit him, they should not be heedlessly changed for any of deeper concavity. It is also advisable not to wear them constantly, but only on occasions when their assistance is absolutely required.

Presbyopia, or *Far-sightedness* (from πρέσβυς, "old," and ὤψ, "eye;" this being a state of vision to which old age is almost invariably subject.)

Long-sightedness, as the name sufficiently indicates, is an affection the reverse of the one just described, and depends upon opposite causes. Either the refractive powers of the eye are too feeble, or its axis is shorter than is natural; the result is an imperfectly formed image on the retina, from the rays of light not converging sufficiently soon to be brought to a focus. Hence the far-sighted person removes the object he is examining farther from him, or he makes use of glasses whose effect is to increase the refraction of the rays of light before they enter his eye. Far-sightedness is sometimes met with in the young; but it is rare that an individual lives to be old without becoming presbyopic: indeed the sinking of the eyeballs, the flattening of the corneæ, and the smallness of the pupils, all which contribute to this effect, are among the series of changes which every part of our body undergoes as we advance in age. The time of life at which presbyopia first shows itself is generally about forty-five; but there are great differences in this respect, some persons requiring the use of convex glasses at thirty as much as others at fifty. Among the earliest symptoms observed, are a difficulty of reading small print, in nibbing a pen, or in examining small objects; the letters of a book appear misty, and run one into another; and if the effort is long continued, the eyes become fatigued and the head aches. Notwithstanding this difficulty of distinguishing near objects, distant ones continue to be seen as clearly as before.

Presbyopia, after it has once appeared, generally goes on increasing, so that an individual thus affected requires to change his glasses from time to time for those of a higher power: instances, however, are recorded of old persons long accustomed to the use of convex glasses recovering their former sight at the age of 80 or 90 years.

Treatment.—The same principles that we have laid down for the treatment of myopia, and for the use of concave glasses, are applicable, regard being had to the opposite condition of the eye, to the present affection. Convex glasses should not be had recourse to too soon, nor should too high a power be used, but the lowest that answers the purpose is to be chosen. When presbyopia occurs suddenly, and in an individual much below the age at which it ordinarily occurs, there is some mischief to be suspected either in the eye or in the brain, which will require an antiphlogistic treatment and a total suspension of the use of the eyes in regarding near or small objects.

Double Vision, *Visus duplicatus*, or *Diplopia*, may arise either from a want of correspondence in the movements or position of the two eyes, the vision of each eye singly being perfect; or there may be double vision with one eye only, while the harmony in the movements of the two is not disturbed. The most common example of the first form of the affection is afforded by cases of squinting; but as this defect is treated of in a separate article, we merely allude to it in this place. More serious and less common is the loss of harmony in the movements of the eyes which results from paralysis of one or more of the orbital muscles. If one muscle only is affected, the eye will move in harmony with its fellow in every direction but the one towards which its paralysed muscle should draw it, consequently in this direction objects will be seen double; but if several are affected, as is not unfrequently the case, then the movements of the eye will be still more restricted, and there will be single vision only when the axis of the sound eye is parallel with that of the paralysed one. These affections appear sometimes to arise from cold; at other times they are dependent upon disease about the base of the brain, as some tumour pressing on the motor oculi nerve, or there may be an inflammatory condition of the brain and its membranes, or a sanguineous or serous effusion involving the origin of the third pair of nerves. Whichever of these may be the cause, our treatment must be directed to remove it, while the state of the eye will be an index of the success or failure of the remedies we make use of.

Double vision with a single eye is a more rare affection than the one just described, and depends upon some irregular refraction of the cornea or lens.

M. Prévost, who published an account of his own case in the 'Annales de Chimie et de Physique,' 1832, thought it might arise from a fracture, bruise, or partial flattening of the lens, or separation of its laminæ. Professor Airy and Mr. Babbage are troubled with this defect, the latter gentleman with both eyes, but he is able to remedy it by looking through a small hole in a card, or through a concave lens. Professor Airy finds that his eye refracts the rays to a nearer focus in the vertical than in the horizontal plane, and he has ingeniously contrived to remedy it by the use of a double concave lens, one surface of which is spherical and the other cylindrical. The spherical surface is to correct the general defect of a too convex cornea; the cylindrical is to converge or diverge those rays at right angles to the axis, while the parallelism of those which impinge upon it in the plane of its axis is unaffected. Thus the focus of the spherical surface will remain unaltered in one plane, but in the other it will be changed to that of a lens formed by it and a spherical surface of equal curvature with the cylinder. With the aid of a glass of this description Professor Airy could read the smallest print at a considerable distance equally well with the defective as with the sound eye. He found that vision was most distinct when the glass was pretty close to the eye and the cylindrical surface turned from it. "With these precautions," he observes, "I find that the eye which I once feared would become quite useless, can be used in almost every respect as well as the other."

Colour Blindness; Dichromism; Chromatopseudopsis; Defect of the Sense of Colour; Daltonism.—There are some persons who, although they can see the size and form of objects perfectly well, have nevertheless a deficient power of distinguishing colour. Many distinguished individuals have been subject to this: such as Dugald Stewart, M. Sismondi, and John Dalton, the celebrated chemist. The subject first excited general attention by the latter distinguished individual having reported his own case, and the deficiency was hence called Daltonism. This subject was investigated by the late Dr. George Wilson, of Edinburgh, who has written a work on 'Colour Blindness' (1855), which contains by far the fullest account of this defect which exists. Dr. Wilson divides the colour-blind into three classes. 1. Inability to discern any colour properly so-called, so that black and white, that is, light and shade, are the only variations of tint perceived. 2. Inability to discriminate between the nicer shades of the more composite colours, such as browns, grays, and neutral tints. 3. Inability to distinguish between the primary colours—red, blue, and yellow; or between those and the secondary colours, such as green, purple, orange, brown. The last variety is the most common. In all these cases it would appear that the primary defect is the inability to distinguish the red colour, and the influence it exerts on the other colours of the spectrum. Dr. Wilson has narrated a large number of cases, and shown that this derangement of vision is much more common than has hitherto been supposed. He calculates from his own observations that at least one person in fifty is thus affected. Dr. Wilson has shown that it becomes very important to know where this defect exists, as it incapacitates people for occupations where the appreciation of colour is important. He has specially shown that, in cases of engine-drivers on railways and sailors at sea, who are warned of danger by coloured signals, this condition may lead to serious disasters.

The cause of this phenomenon has occasioned much discussion. Dalton attributed it to the condition of the humours of the eye; but a careful examination of his eyes after death, by Mr. Ransome, revealed nothing to account for the defect. It has been supposed by others that the defect is connected with the organisation of the brain. Recently Professor Clark Maxwell, of Cambridge, who has written a paper 'On the Compound Theory of Colours,' in the 'Philosophical Transactions' for 1860, explaining his views, has proposed another theory, which has been generally accepted. He has shown that the three primitive colours are not, as usually regarded, red, yellow, and blue, but red, green, and blue, as pointed out by Young. He has also adopted Young's theory that there is a distinct retinal structure for the perception of each colour, and shown how the remarkable defect of appreciation of the red rays occurs in the colour-blind. Professor Maxwell has also suggested the only means of alleviating this defect which has hitherto been recommended, and that is the wearing of spectacles composed of red and green glass simultaneously. A spectacle frame of the usual kind is constructed with one glass red, the other green, so that the right eye, for example, of the wearer of the spectacles looks always through red and the left always through green. Through the red glass red objects appear *brighter* than green ones, through the green glass green objects appear brighter than red ones, so that a colour-blind person puzzled between red and green has only to determine whether the doubtful colour appears brighter to the right or the left eye, and to set it down as the colour of the glass which brightens it. (See Maxwell 'On Colour as perceived by the Eye, with remarks on Colour-Blindness,' 'Trans. Roy. Soc. Edin.,' 1854–5, vol. xxi. part ii.)

SIGN (Astronomy), a constellation; but in modern times a constellation of the ZODIAC only. For the distinction of the sidereal and astronomical zodiac, see PRECESSION.

SIGN (Mathematics). Every symbol is a sign of something or other, the original meaning of the word applying to any mark of distinction or designation. The general consideration of the subject of signs comes under the word SYMBOL; for this term, sign, is exclusively applied in mathematical analysis to the signs of addition and subtraction (+ and −). A positive quantity, as +3, is said to have the positive sign; a negative quantity, as −3, the negative sign.

The theory of these signs is the peculiar feature of ALGEBRA, as distinguished from arithmetic; and it is difficult to place it on any satisfactory basis except that of distinct definitions not wholly derived from arithmetic. On this point, however, it is not our present purpose to enter further; the object of this article being the application of the signs, and in particular those details of interpretation which are necessary in the application of ordinary algebra to geometry. By ordinary algebra we mean that system in which the positive and negative quantities are fully capable of interpretation, but in which $\sqrt{-1}$ is considered as incapable of interpretation.

The relative meaning of + and − is direct opposition of properties; and it is only where direct opposition is possible that complete interpretation can exist. The symbol +7 means not only 7 units of its kind, but 7 units directed to be considered in a specific one of two (the only possible) lights, or used in a specific one of two (the only possible) manners; the first generally implying the second. Thus let 7 inches be measured from a given point; the superposition of + or − tells nothing, for the measurement may be made in an infinite number of different directions. Choose one of these directions, or rather one line of direction, and the indeterminate character of the proposal (to measure seven inches from the given point) is almost gone: there are but two directions in which to do it; if one of them (no matter which) be signified by +7, the other (no matter which, except with reference to the first) must be denoted by −7.

A problem may present different sets of oppositions of very different kinds. Thus we might have a problem in which there are concerned together—1, time before or time after a certain epoch; 2, height above or height below a certain level; 3, the debtor or creditor side of certain books. To give a more precise idea (it is hardly worth while to frame a specific problem), a man might engage to build a wall on different terms as to the foundation and what is above the ground; for which he might have to borrow money and pay interest up to a certain time, when by receiving the whole amount due to him he might repay and invest besides; and the whole transaction might have to be properly entered in his books. The young student might suppose that if + 1 and −1 represent a foot of the wall above and a foot below the ground, it will not necessarily follow that + 1 and − 1 (undistinguishable from the former) will do to represent one pound of interest due to and from the contractor; and still less that the same + 1 and − 1 will also do to direct 1*l.* to be carried to the debtor or creditor side of his books. But what he will learn from a properly established algebra (and until he has learnt it, he is not in possession of any part of the difference between algebra and arithmetic) is this—that he would gain absolutely nothing by inventing such distinctive symbols as would remove his doubt of their applicability. Let (+)1 and (−)1 represent feet of wall, [+]1 and [−]1 pounds sterling of interest, {+}1 and {−}1 pounds sterling carried to one side or the other of the books; while + 1 and − 1 represent simple addition or subtraction. Let the problem be fairly translated into algebraical language, and an equation formed in which all the distinctive symbols are seen: algebra teaches that the rules to be applied to that equation differ in no respect whatever from those which would have been applicable if all the signs had come from the same source of meaning. Perhaps it would be better if the student were not allowed to come so easily by this result as he usually does, but should be made to learn by his trouble how unnecessary the distinctions really are, as to operations, and allowed in due time to feel the relief afforded by dropping them.

When a problem admits of but one opposition (say it simply refers to time measured future or past from a given epoch), there is no difficulty about the interpretation of any result. If this result be positive, it must be such time as was called positive when the operation was put into shape; and the contrary. But in the application to geometry, an extension of the interpretation of signs enables us to remove some difficulties in the proper expression of angles, which we proceed to describe.

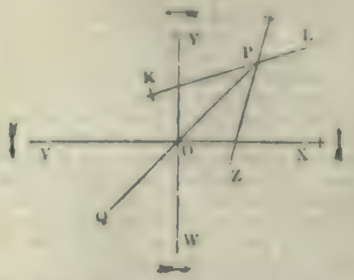
In the rectilinear figures considered by Euclid the sum of the external angles is always equal to four right angles. In these figures there are no re-entering angles. [SALIENT.] The proposition remains true when there are re-entering angles, provided that the angles which then take the place of what were called *external* angles be counted as negative. In algebraic geometry it is usual to refer all points and lines to two straight lines at right angles to one another. [ABSCISSA; CO-ORDINATES.] The following conventions must now be employed:—

1. Let VX and WY be the axes of co-ordinates, meeting at O, the origin. Let OX and OY be positive directions: OV and OW, negative directions.

2. A line drawn from O to any point P is in itself (for the present) neither positive nor negative; either sign may be given to OP, but the contrary one must be given to OQ.

3. The line OP may, keeping its sign, revolve round O; nor, if negative, is it to be counted positive when it comes into momentary coincidence with OX; nor, if positive, is it to be counted negative when in coincidence with OV. And generally, a straight line revolving round any point does not take the signs of lines which receive signs on account of the fixed directions in which they are drawn.

4. The angle made by two lines A and B is to have a distinction of sign drawn, according as it is called the angle made by A with B, or the angle made by B with A (the angles made by A *from* B, and by B *from* A, would be better). If the angle of A with B (say A^B) be positive, then the angle made by B with A (B^A) is negative, and *vice versâ*.



5. The positive direction of revolution is that in which a line moves from the positive part of the axis of x to the positive part of the axis of y (as marked by the arrows).

6. The sign of any line drawn through P is thus determined. If OP be *positive*, that direction is positive in which the point P must move so as to revolve *positively*; thus, OP being positive, PK is positive and PL negative. But if OP be negative, the reverse is the case; but the rules need only be remembered which suppose OP positive.

7. When an angle amounts to more than four right angles, the four right angles may be thrown away; and generally, four right angles, or any multiple of them, may be added to or subtracted from any angle.

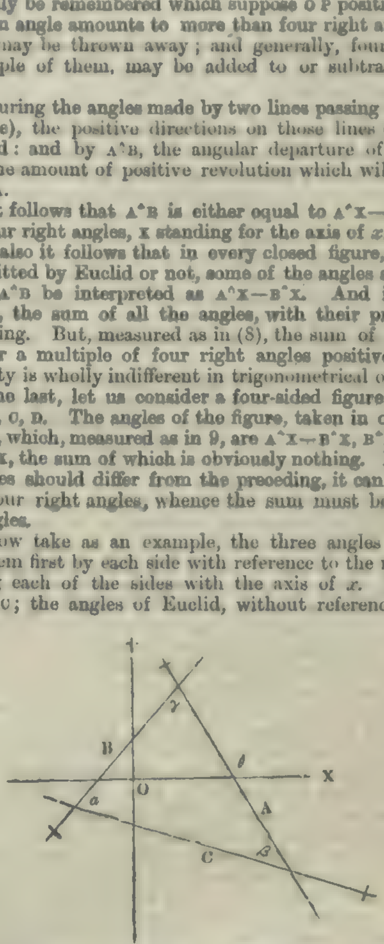
8. In measuring the angles made by two lines passing through P (OP being positive), the positive directions on those lines (found as in 6) must be used: and by A^B, the angular departure of A from B, is understood the amount of positive revolution which will bring B into the position A.

9. Hence it follows that A^B is either equal to A^X−B^X, or differs from it by four right angles, X standing for the axis of x.

10. Hence also it follows that in every closed figure, whether such as those admitted by Euclid or not, some of the angles are negative, if every angle A^B be interpreted as A^X−B^X. And in every such measurement, the sum of all the angles, with their proper signs, is equal to nothing. But, measured as in (8), the sum of all the angles is nothing, or a multiple of four right angles positive or negative. This ambiguity is wholly indifferent in trigonometrical operations.

To prove the last, let us consider a four-sided figure, of which the sides are A, B, C, D. The angles of the figure, taken in order, are A^B, B^C, C^D, D^A, which, measured as in 9, are A^X−B^X, B^X−CX, ^C^X−D^X, D^X−A^X, the sum of which is obviously nothing. But if any one of these angles should differ from the preceding, it can be only by a multiple of four right angles, whence the sum must be a multiple of four right angles.

We shall now take as an example, the three angles of a triangle, estimating them first by each side with reference to the next, and then by comparing each of the sides with the axis of x. The sides are marked A, B, C; the angles of Euclid, without reference to sign, are



α, β, γ: and the positive and negative directions are marked. Four right angles are denoted as usual by 2π. Required A^B + B^C + C^A.

In A^B, the amount of positive revolution by which the positive part of B turns round into that of A is $\gamma+\pi$. Similarly for B^C, we have $\alpha+\pi$, and for C^A, $\beta+\pi$. The sum of these, $\alpha+\beta+\gamma$ being π, is 4π, a multiple of 2π. Now let the angle A^X be θ. Then B^X will be seen to be an angle in this figure greater than two right angles, and will be found to be $\pi+\theta-\gamma$, while C^X is greater than three right angles, and is $2\pi-\alpha+\theta-\gamma$. Hence we have

$$\begin{aligned}
\mathrm{A}\,\hat{}\,\mathrm{B} &= \theta-(\pi+\theta-\gamma)=\gamma-\pi\\
\mathrm{B}\,\hat{}\,\mathrm{C} &= \pi+\theta-\gamma-(2\pi-\alpha+\theta-\gamma)=\alpha-\pi\\
\mathrm{C}\,\hat{}\,\mathrm{A} &= (2\pi-\alpha+\theta-\gamma)-\theta \qquad\quad =\beta+\pi.
\end{aligned}$$

Only the third angle gives precisely the same in both; in the other two, the second determination gives in each case four right angles less than the first. The sum of the three angles is now 0.

The use of this system lies in enabling us to give in a general form propositions which would otherwise require a large examination of particular cases. This examination is not usually made in elementary works; but instead of it, the true result, derived from the superior knowledge of the writer, is made to the reader the consequence of a particular case. In the consideration of curves, for instance, there are to be considered, perhaps at the same time, the co-ordinates, the radius vector, the tangent, the perpendicular on it, and the radius of curvature. The varieties of figure which arise out of these lines are very numerous, and nothing but generalised suppositions, competent to assign definite angles in all cases, can legitimately bring out general propositions. For instances, see TANGENT, SPIRAL; and for further development, see 'Library of Useful Knowledge,' Differential Calculus, pp. 341-345.

SIGN-MANUAL means, in its widest sense, the signature or mark made by a person upon any legal instrument to show his concurrence in it. Before the art of writing was so universally practised as it now is, the sign-manual or signature was usually a cross, attested either by the seal of the party containing his armorial bearings, or by the signature of another person declaring to whom the mark belonged. The latter indeed is still the practice with persons who cannot write.

Sign-manual now however is used to denote the signature of a reigning prince. It is usually in this country the prince's name, or its initial letter, with the initial of his style or title in Latin. Thus the sign-manual of George IV., when prince regent, was George P. R., or G. P. R.; that of the present queen is Victoria R., or V. R.

The royal sign-manual is usually placed at the top left-hand corner of the instrument, together with the privy seal; and it is requisite in all cases where the privy seal and afterwards the great seal are used. The sign-manual must be countersigned by a principal secretary of state, or by the lords of the treasury, when attached to a grant or warrant, it being then the principal act, and it must also be accompanied by the signet or privy seal. But where the sign-manual only directs that another act shall be done, as for letters-patent to be made, it must be countersigned by some person, though not necessarily by these great officers of state. The authenticity of the sign-manual is admitted in courts of law upon production of the instrument to which it is attached. (Comyn's 'Digest.')

SIGNATURE, in Music, is the term by which the clefs and sharps or flats placed at the beginning of each staff are, collectively, known, and by which the key is partly shown. See KEY, where the *Signature* in every key is given.

SIGNATURE, in Printing, is the name given to the letters or figures which are placed at the bottom of certain pages in each sheet of a book, to facilitate the gathering, folding, collating, and binding of it. The French printers generally use figures, but English printers for the most part use small capital letters. The bookbinders' alphabet, as it is called, contains only 23 letters (*j*, *v*, and *w* being omitted); and as the title-sheet, which contains the dedication, preface, &c., is generally printed last, the signatures of the work itself commence with B, leaving A for the title sheet. If there be other introductory matter besides the title-sheet, small letters, as a, b, &c., are used till the work itself is reached. If the work contain more than 23 sheets, the second set of signatures are AA, BB, or more commonly 2 A, 2 B, &c.; and the third set 3 A, 3 B, and so on. If the work is in folio it requires only one signature; if in 4to or 8vo, it requires two, as, for instance, B on the first page and B 2 on the third; if in 12mo, it requires three, as B on the first page, B 2 on the third page, and B 3 on the ninth page; and so on for printed works of other forms.

SIGNET, SEAL. The law recognises three royal seals:—1, The great seal, which is in the custody of the lord chancellor: this is appended to all letters-patent, and contains two impressions, the one being usually the sovereign on horseback, the other the sovereign seated, supported by emblematical figures, and with the coat of arms somewhere in the field. The great seal is essential to all royal grants of inheritances or chattels real, to grants of an office in fee, and to all writs at common law. Where the king's seal is mentioned, it is understood to be the great seal. 2. The privy seal, which is in the custody of the lord keeper of the privy seal. This seal is valid for the issuing of the royal treasure, or for disposing of chattels, or the contracting or discharging of a debt. It is used as a warrant for letters-patent before they pass the great seal. The privy seal consists of the arms of the sovereign. 3, The signet, or privy signet, which is in the custody of the principal secretaries of state. Except that it authenticates the sign manual, this seal seems to have no validity, although it is alleged to be sufficient to give validity to the writ *ne exeat regno*, whereby a subject is prohibited from going out of the realm. For the use of all the seals the countersignature of a principal secretary of state is required by statute. [SEAL.]

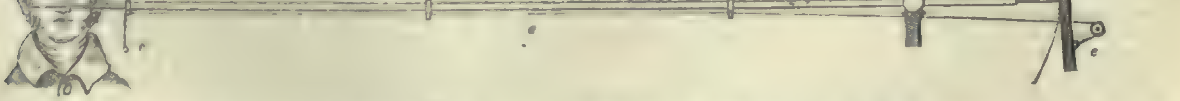
SILE'NUS (Σειληνός), a Greek deity. The traditions of his birth are various: he is said to be the son of Pan and of a nymph; of Gæa; and to have sprung from the blood of Uranus. He was the instructor and constant associate of Dionysos; was a lawgiver and prophet, sometimes confounded with Dionysos himself; of the family of Satyrs, whom he resembled very much in appearance and habits. He is represented as an old unwieldy man, bald, with a beard, and depressed nose, sometimes with a tail; at times holding the infant Bacchus in his arms; sitting astride a wine-skin, or carrying one on his shoulders. He has a conspicuous place in the Dionysian processions, and occurs in various combination with fauns and nymphs; sometimes he rides on an ass reeling and supported by a satyr; and sometimes he is carried by youthful satyrs. Though endowed with supernatural wisdom, he is of a jovial disposition; his whole character is a mixture of jest and earnest; he is harmless, sportive, fond of children; addicted to wine; is said to have conducted Dionysos from Thrace to Phrygia; and to have been ensnared by Midas in a garden, and compelled to exert his marvellous power of speech. His discourse, always ironical, was of the second world, of the land of Meropis, and of its strange men, beasts, and plants, of the origin of things and birth of the gods, and he showed the miserable condition of this present life. The ass by which he is accompanied has given rise to many conjectures; the Dionysian myths and those of Apollo speak of this animal as sacred to both deities. It may therefore be considered as the link uniting the two worships; and we find accordingly Apollo called the son of Silenus. (Porphyry, 'Vit. Pythag.,' p. 10, ed. Rome, 1630.) Attempts have been made by Bochart and others to connect Silenus with the name Shiloh in Scripture, and his ass with that of Balaam. Other imaginary resemblances are noticed by Creuzer ('Symbolik'), founded on the theory that the ass is the symbol of prophecy in the East.

The distinction between Sileni and Satyrs appears to be that the Sileni are the older of the two. The terms were certainly not co-extensive; that of Satyr may be considered as the genus; but they are represented much in the same manner. See, for representations of Silenus, Creuzer's 'Symbolik,' Grüber's 'Wörterbuch der Mythologie,' and Müller's 'Denkmäler der Alten Kunst' (Nos. 494-522); Millin's 'Galérie Mythologique,' and the various works on gems, sculpture, vases, and other monuments of classical antiquity.

SILEX. [SILICON.]

SILHOUETTE, a name applied to the black profile portraits, commonly known simply as *profiles* or *shades*. The latter name indicates the origin of this simple class of pictorial representations, they having been probably suggested by the shadow thrown upon a wall. The name *silhouette* has been said to be derived from Etienne de Silhouette, French minister of finance in 1759. It appears that several parsimonious fashions introduced during his administration, in order, by severe economy, to remedy the evils of a war that had just terminated, were called, after this minister, *à la Silhouette*, and that the name has continued to be applied to one of them—the use of profiles in shade.

Silhouettes are executed in various ways. One of the simplest is that of tracing the outlines of a shadow thrown on a sheet of paper, and then reducing them to the required size, either by the eye or by means of a pantograph. [PANTOGRAPH.] The camera-obscura and camera-lucida are also occasionally used for the purpose. A more certain mode of obtaining an accurate outline is by the use of the machine invented for the purpose by Mr. Schmalcalder, and patented by him in 1806. The principle of this machine is very simple, and may be readily understood by the aid of the annexed diagram. *a b* is an inflexible rod, usually about nine or ten feet long, supported by a ball-and-socket joint at *c*, in such a manner as to leave the ends free to move in any direction. At the end *a*, a *tracer*, which is tapered off to a fine point, is attached to the rod, so as to form a continuation of it; while at the opposite end, *b*, a steel point is similarly fixed. The person whose profile is required is seated, in the position indicated in the cut, in a chair having a rest for the back of the head, in order that he may sit perfectly still, while the operator gently passes the side of the tracer, *a*, over his features. By the intervention of the universal joint (or of a double-swivel joint) at *c*, a perfectly similar motion is communicated to the steel point at *b*, although, owing to the pivot being placed nearer to it than to the other end of the rod, it moves in a path smaller than that of the tracer *a*. The pivot *c* being stationary, the steel point at *b* moves in the arc of a circle of which it (the pivot) is the centre, as indicated by the dotted line in the diagram; and therefore, in order to keep the paper always in contact with it, it is fixed on a swinging board, pivoted at *d*, and constantly pressed against the steel point by means of a weight or spring, with a sufficient degree of force



to make it act efficiently. The steel point does not come into immediate contact with the white paper, but with a piece of blacked paper placed over it, the pressure of the point transferring a sufficient quantity of the colour to form a distinct line. This part of the operation resembles that of a manifold writer; and, as in that instrument, several copies may be produced simultaneously, by using a number of pieces of white and blacked paper, laid alternately upon the swinging board. The size of the reduced outline drawn on the paper may be regulated by varying the relative proportions of *a c* and *c b*; this and several other adjustments being effected by apparatus which it is unnecessary here to detail. By means of a cord, *c c c*, held in the hand of the operator, the swinging board *d* may be drawn back from the steel point when it is required to move the rod without making a mark upon the paper. Greater accuracy may be attained by substituting for the tracer a thin wire, tightly stretched in a bow, and adjusted so as to coincide perfectly with the axis of the rod. In some cases a kind of knife is substituted for the steel point at *b*, and the profile is thus cut out of a piece of thin black paper placed on the swinging board. Some profilists display considerable talent in cutting silhouettes by hand, with a pair of scissors, out of pieces of black paper, without the assistance of an outline.

SILICA. [SILICON.]

SILICIC ACID. [SILICON.]

SILICIUM. [SILICON.]

SILICOFLUORIC ACID. [SILICON.]

SILICON (Si). *Silicium.* With the exception of oxygen, silicon is the most abundant constituent of our earth's crust. Its name is derived from *silex*, Latin for "flint," of which the essential component is silicon. The element silicon has great affinities for other elements, and hence does not exist, in nature, in the free state. Its common, and apparently sole, native form of combination is an oxide known as *silex* or *silica.* Rock crystal and white quartz are nearly pure varieties of silica; while calcedony, agate, opal, flint, and sand are chiefly silica. The natural compounds of silica with oxides are almost innumerable. The individuality of siliceous minerals was recognised at a very early period, but their constitution was not demonstrated till the commencement of the present century.

Silicon itself was first isolated only so lately as 1823. It may be prepared by reducing an alkaline silico-fluoride with potassium, in a glass or iron tube, at a high temperature. It may also be obtained by passing chloride of silicon vapour over potassium heated in a bulbed glass tube.

Silicon, like CARBON and BORON, exists in three distinct modifications. As above prepared, it is a dull-brown powder; insoluble in, and heavier than, water; is a non-conductor of electricity, is soluble in hydrofluoric acid, and in a warm solution of potash; burns readily and brilliantly when heated in the air; and is moreover *amorphous* (Siγ). If the amorphous silicon be strongly heated it becomes semicrystalline or *graphitoidal* (Siβ); is denser and darker in colour; does not burn in oxygen: is not soluble in hydrofluoric acid; and is a conductor of electricity. *Crystalline* silicon (Siα) occurs in the form of six-sided prisms or pyramids, whenever the process for its preparation has included the application of the most intense heat of a wind furnace.

The equivalent of silicon has, in turn, been represented as 7, 14, 21, and 28; but since the experiments of Marignac, who proved that the fluo-stannates and fluo-silicates are isomorphous, it has been usual to consider the number 14 as the true equivalent of silicon.

Silicon and *oxygen* form two compounds:—

1. Hydrated protoxide of silicon . .	$2HO, 3SiO$
2. Silicic acid	SiO_2

1. *Hydrated protoxide of silicon* ($2HO, 3SiO$).—When dry hydrochloric acid gas is passed over crystallised silicon, heated to incipient redness, hydrochlorate of protochloride of silicon ($2HCl, 3SiCl$) is produced, and may be condensed to the liquid state in a U-tube cooled by ice; hydrogen passes off carrying vapour of protochloride with it; the gas being allowed to bubble through water the chloride is decomposed, and a voluminous white precipitate of the oxide under consideration is formed:—

$$2HCl, 3SiCl + 5HO = 2HO, 3SiO + 5HCl.$$

Hydrated protoxide of silicon sinks in water but floats on ether; the caustic alkalies and their carbonates dissolve it with evolution of hydrogen and formation of silicate; it may be heated to 570° Fahr., without undergoing alteration, but at a higher temperature burns; and in contact with water undergoes oxidation, hydrogen being evolved, at any temperature above 32° Fahr.

2. *Silicic acid* (SiO_2), *Silex, Silica, Binoxide of silicon.*—The physical and chemical properties of the many different forms of silica that occur in nature, as well as a list of the minerals in which silica is a characteristic constituent, have already been treated of in the NATURAL HISTORY DIVISION of this Cyclopædia, article SILICA.

Silicic acid is largely used in the manufacture of glass, chinaware, and porcelain. For these purposes it is obtained in a fine state of division by igniting flints or colourless quartz to redness, and then plunging in cold water. The compact silica is thus split up into a friable mass, easily reducible to powder by grinding. Perfectly pure silicic acid may be obtained by igniting hydrated silica.

Hydrates of silicic acid (xHO, SiO_2).—Finely powdered silica is soluble in strong alkaline solutions if heated with them under pressure; from the resulting solutions hydrated silica is precipitated in a very gelatinous state on neutralising by hydrochloric acid. The alkaline silicate may also be formed by fusing powdered flint, &c., with the carbonates of potash or soda; if excess of the latter be used, the silicate is soluble in water, and the solution furnishes hydrated silicic acid on the addition of hydrochloric acid. Perfectly pure hydrated silica is formed in a very beautiful manner on passing gaseous fluoride of silicon into water, each bubble of gas forming a little balloon of silica; hydrofluosilicic acid (HF, SiF_2) is also formed at the same time, and remains dissolved in the water:—

$$\underbrace{3SiF_2}_{\text{Fluoride of silicon.}} + \underbrace{4HO}_{\text{Water.}} = \underbrace{2HO, SiO_2}_{\text{Hydrated silicic acid.}} + \underbrace{2(HF, SiF_2)}_{\text{Hydrofluosilicic acid.}}$$

Isomeric conditions of silica.—Professor Rose has recently directed attention to the two different states in which silica exists. Crystallised silica—including rock-crystal, quartz, calcedony, flint, sandstone, and quartzose sand—has a specific gravity, of about 2·9, and is only attacked with difficulty by potash, or hydrofluoric acid. Amorphous silica, on the other hand,—including gelatinous silica, the pulverulent variety that results from the decomposition of certain minerals, or of fluoride of silicon by water, opals, melted quartz, and silica from the carapaces of infusoria—is very readily soluble in alkaline solutions, is rapidly acted upon by hydrofluoric acid, and has a specific gravity of 2·2.

Silicates, as a general rule, are insoluble in water. Alkaline silicates are however, soluble in that liquid, and their solutions have lately been used as a varnish for the stonework of buildings with the view of preventing decay. When thus exposed to the atmosphere, the silica, being but a weak acid, is replaced by carbonic acid; the alkaline carbonate is removed by rain, and silicic acid filling up the pores of the stone is supposed to prevent ingress of moisture or other disintegrating matter. The fact is, however, that the decomposition alluded to, being but a slow one, a large portion of the silicate is washed away by the rain, and this process is consequently of but little value. A modification of the method, known as "Ransome's patent," consists in supplementing the application of the alkaline silicate by a wash of chloride of calcium; silicate of lime is hereby at once produced, and performs the office of a permanent varnish or cement, in a far more efficient manner than the mere silica before alluded to. Clay, talc, felspar, serpentine, mica, zeolites, hornblende, and many other minerals, consist of, or contain, silicates of lime, or magnesia, or alumina, or a mixture of those silicates. They are either *sesquisilicates* like meerschaum ($2MgO, 3SiO_2 + 2HO$), or *neutral silicates*, like Wollastonite (CaO, SiO_2); or *dibasic silicates*, like olivine ($2(Mg, Fe)O, SiO_2$); or *bisilicates* ($MO, 2SiO_2$). [SILICA, in NAT. HIST. DIV.]

Silicon and *hydrogen* form a *hydride of silicon.* Berzelius first showed that the hydrogen which is evolved when crude silicon is washed with water, contains a hydride of silicon. This gas has not yet been procured in a pure state, but, according to Wöhler and Buff, it is colourless and spontaneously inflammable. It occurs in the latter condition when a solution of a chloride is electrotised by a weak voltaic battery of which the positive pole is aluminium contaminated with silicon.

Nitride of silicon is a bluish, fibrous-looking body, formed when silicon is heated in nitrogen gas.

Sulphide of silicon (SiS_2).—Silicon burns in sulphur vapour, generating bisulphide. The same body may be formed on passing bisulphide of carbon over a heated mixture of carbon and silica. It is a white, earthy-looking powder.

Bromide of silicon may be obtained, but *iodide* does not seem to exist.

Silicon and *chlorine* form two compounds corresponding to the two oxides.

1. *Hydrochlorate of protochloride of silicon* ($2HCl, 3SiCl$).—The method of preparing this body has already been described in connection with protoxide of silicon. It is a colourless liquid, refracting light powerfully; emits suffocating fumes on exposure to air; is inflammable, burning with a pale green flame; and is decomposed at a red heat.

2. *Chloride of silicon* ($SiCl_2$), or rather, *bichloride* of silicon.—Finely powdered silica is made into a dough-like mass with lampblack and oil, and heated to redness in a covered crucible; a porcelain tube filled with fragments of the resulting mass is strongly ignited and a current of dry chlorine passed through it; the following decomposition occurs:—

$$\underbrace{SiO_2}_{\text{Silica.}} + \underbrace{Cl_2}_{\text{Chlorine.}} + \underbrace{C_2}_{\text{Carbon.}} = \underbrace{2(CO)}_{\text{Carbonic oxide.}} + \underbrace{SiCl_2}_{\text{Bichloride of silicon.}}$$

The chloride of silicon vapour must be condensed by the aid of a freezing mixture, for it is very volatile. It is a transparent, colourless liquid; fumes in the air, and has an irritating odour.

Chlorosulphides of silicon ($SiS_2, 2SiCl_2$) and ($2SiS_2, SiCl_2$) may be formed by the reaction of chloride of silicon vapour and dry hydrosulphuric acid gas at a red heat.

Fluoride of silicon (SiF_2) or *fluosilicic acid*, and *silicofluoric* or *hydrofluosilicic acid* (HF, SiF_2) have been described under FLUORINE.

Detection of silicon.—The presence of this element in such a substance as glass, or any transparent mineral, is readily demonstrated by the etching action of hydrofluoric acid. From solution it is precipitated as gelatinous silica on the addition of hydrochloric acid. Silica may also be individualised from its property of being after ignition insoluble in all acids, except hydrofluoric, but soluble in fused caustic alkali.

Estimation of silicon.—This is always performed in the state of recently dried and anhydrous silica, which contains 46·7 per cent of silicon, and 53·3 of oxygen.

SILK MANUFACTURE. This subject naturally divides itself into four parts:—The rearing of the insect which yields the silk; the extrication of the filament in a state fitted for the manufacturer; the spinning and weaving into textile fabrics; and the commercial arrangements arising out of the manufacture. Such portions of the subject will be treated here as have not yet been noticed in the Cyclopædia; for the rest, cross-references will suffice.

Rearing silk-worms.—Silk is produced by a small insect, in the manner described in BOMBYCIDÆ, NAT. HIST. DIV. China was undoubtedly the country in which men first availed themselves of the labours of the silk-worm. Serica (the country of the Seres) was a name by which the Macedonian Greeks designated the country which produced the silk that came overland from the north of China. The author of the 'Periplus of the Erythræan Sea' speaks of silk in Malabar as an article imported from countries farther to the east; from which it may be inferred that the culture of the silk-worm and the manufacture of silk had not been introduced even into India four hundred years after silk was known in Europe. In speaking of the country of the Thinæ, the same author observes that both the raw material and manufactured article were obtained there. The "Median robes," spoken of by the Greek writers of the period of the Persian empire, and extolled for their lustrous beauty and brilliancy, were no doubt silken vestments; as Procopius long afterwards, when silk had been introduced into Europe, states that "the robes which were formerly called Median by the Greeks are now called silken." Aristotle is the first Greek author who mentions the silk-worm ('Nat. Hist.,' v. 19). He states that silk was first spun in the island of Cos, but that the raw material was still an oriental product; and Pliny (xi. 22), in commenting on this passage, states that the silk came from Assyria, and was worked up by the Greek women. It may be remarked that Assyria was, like Media, frequently used in an indefinite sense by ancient writers. The probability is that silk was used in Western Asia before it was known to the Greeks; and that it was in use among the Greeks long before they knew whence the substance came or how it was produced.

Pausanias is perhaps the first who gives precise information respecting the substance from which the Seres formed their cloths. "They have," he says, "a spinning insect, which is kept in buildings, and produces a fine-spun thread, which is wrapped about its feet" (vi. 26). It was not until the sixth century that the obscurity which enveloped this subject was cleared up. At this time silk was an article of general use among the Romans, and was manufactured for them by the inhabitants of Tyre and Berytus in Phœnicia. The Persians monopolised the supply of the raw material, and guarded their trade with so much jealousy, both by land and sea, that travellers from or to China were not allowed to traverse the Persian dominions; and in the time of Justinian, in consequence of some interference with the trade, they had entirely stopped the importation of silk. The trade in silk was in this unsatisfactory state, when two Nestorian monks of Persia, who had travelled to China, acquainted Justinian with the mode of producing silk, and undertook to return and bring back with them some of the eggs of the silk-worm. They were perfectly successful in their expedition; for a quantity of eggs, secured in a hollow cane, were brought in safety to Constantinople, hatched by the heat of a dunghill, and fed with mulberry-leaves. The monks also taught the subjects of Justinian the art of manufacturing silk.

The breeding of silk-worms in Europe was for six centuries confined to the Greeks of the Lower Empire. In the 12th century the art was transferred to Sicily; in the 13th century the rearing of silk-worms and the manufacture of silk were introduced into Italy, and from thence successively introduced into Spain and France.

James I. was solicitous to promote the breeding and rearing of silk-worms in England; and in 1608 issued circular letters, which were addressed to persons of influence throughout the country, recommending the subject to them; but the experiment was unsuccessful. Most of the old mulberry trees found in the neighbourhood of ancient mansions in England at the present day were planted at this period. The experiment has also failed, though several times attempted, in North America.

The production of raw silk is fast extending in British India, and the quality has been for some years gradually improving. In Graham's 'India,' it is said that in the Deccan the mulberry-trees may be deprived of their leaves six times a year, and that six crops of worms may be obtained with ease in the same period. The Chinese method of rearing silk-worms, and their mode of treating the mulberry-tree (described in Davis's 'China,' p. 280), were introduced at St. Helena, under the auspices of the East India Company; but on the expiration of their charter the establishment was given up. Some of the silk produced in France is believed to be better than that of any other country in the world. The Italian silk is also highly esteemed.

There has recently been a very earnest attempt made to disseminate the silk-worm culture in various parts of Europe. In 1854 some silk-worm eggs, reared at Assam, were brought from Calcutta to Malta, through the aid of Mr. Piddington. They were not the usual kind, but a variety called the *Bombyx cynthia*, which feeds on the castor-oil plant. Sir William Reid, Governor of Malta, caused these eggs to be carefully tended; 500 of them were hatched, and fed on the castor-oil plant. After some time, portions of the store were sent to Piedmont, France, Algiers, and the West Indies, in order that fair trials might be made in different climates. It is known that the castor-oil plant suffices to give the worms the silk-producing power; for the Assamese make shawls, dhoties, coverlets, coats, turbans, and women's dresses, with silk thus obtained. Early in 1855 it was found that the worms at Malta declined and died off, from some cause not clearly traceable; and the attempt failed, so far as that island was concerned. In 1856, however, some of the eggs reached Prussia; and great endeavours are now being made to foster the culture in Germany, Sweden, and Russia. The silk produced by this kind of worm is not so fine as the mulberry-silk; but is believed to be more easily worked, if the insect can only be made to thrive. As to England, silk-worm rearing has been to the present day, and still is, nothing more than an amusement, or an experiment having no commercial value.

This may be the proper place to say a few words concerning other filaments of the nature of silk. The web of many kinds of caterpillars has been found nearly equal to silk, and gloves and stockings have been made of it; but Reäumur found that 50,000 of the insects were needed to yield 1 lb. of silk, and, moreover, that the caterpillars showed a very unprofitable tendency to kill and eat each other. Some fabrics exquisitely light, others moderately strong, have been made from caterpillar filament, but hitherto without commercial success. The *pinna*, a gigantic kind of mussel found in the Mediterranean and the Indian Ocean, fastens itself to rocks with a kind of cord made of beautiful silky filaments; these filaments may be worked up in the manner of silk; but the supply is too small to render the matter other than a curiosity. Very recently there was landed at Liverpool a small quantity of *pulu* or vegetable silk, obtained from the lower part of the stalk of a fern growing in Sumatra; the stalk is covered with a kind of sparkling golden-brown hair, which can be detached and worked up as silk. About 3 ounces can be obtained from each plant. The substance has not yet attracted much attention in England, but is beginning to be worked in America.

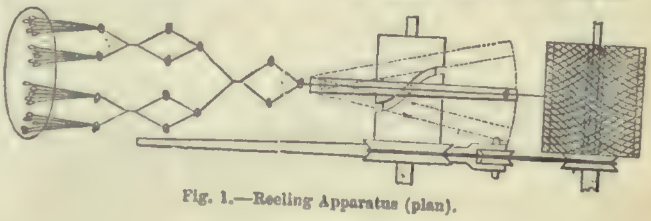


Fig. 1.—Reeling Apparatus (plan).

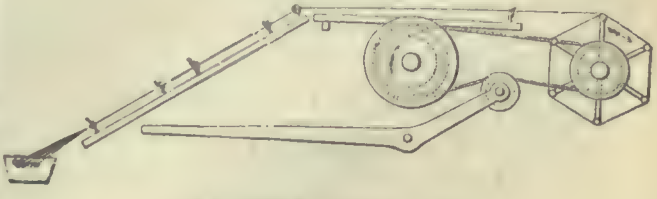


Fig. 2.—Reeling Apparatus (section).

The Cocoons and Silk Reeling.—The cocoons [BOMBYCIDÆ, in NAT. HIST. DIV.] average in weight about 3 grains each; the average length of silk upon each, when reeled off, is about 300 yards; and 12 lbs. of cocoons are required to yield 1 lb. of reeled silk—so many are the impurities to be got rid of. About 1 ounce of silk-worm eggs will produce 100 lbs. of cocoons; 16 lbs. of mulberry leaves will afford food sufficient for the production of 1 lb. of cocoons; and each mulberry tree will yield about 100 lbs. of leaves. These figures will afford easy means of calculating the number of insects, eggs, trees, leaves, &c., necessary for the production of 6,000,000 or 8,000,000 lbs. of silk—about the annual consumption of the United Kingdom. *Reeling*, or the drawing off of the silken filament from the cocoon, is usually done only in the countries where the worm is reared. To effect this, the worm is not allowed to die a natural death; the cocoon is exposed to the heat of the sun or of an oven until the insect is stifled. An external soft envelope is removed, constituting *floss silk*; the real silk is wound closely around the cocoon, in an agglutinated mass. The cocoons are steeped in hot water until the gum is dissolved. The reeler (a woman or girl), with a kind of whisk or brush, detaches the ends of ten or twenty filaments from as many cocoons, winds them two or three together on a reel, then two or three of these groups together, and so on until all form one thread, very much thicker than the original filament, but still exceedingly fine. New cocoons are thrown into the vessel of hot water as fast as the old ones are exhausted, so that the thread is made continuous; and the temperature of the water is such as will enable the cocoons to give off the filaments just as fast as the reeler can wind them. In some districts the reeling is done in a quicker and better way, by aid of the apparatus shown in *fig.* 1 (plan), and *fig.* 2 (section). From the reel the silk is made up into *hanks*, which present different appearances, according to the countries whence they are obtained. Broussa and China hanks are whiter than the others; Bengal hanks are small; Italian are larger; and Persian are the largest and coarsest of all.

Such is the simple operation of reeling. It has been a conventional opinion that this can only be done in the silk rearing countries; because the cocoons cannot be conveyed long distances safely, and because a clear and warm climate is necessary. The correctness of this opinion is now disputed. Mr. Dickins, a silk dyer at Middleton, and Mr. Chadwick, a silk manufacturer at Manchester, have invented and set to work a system of apparatus for reeling silk in England, and throwing or twisting the silk so reeled. The cocoons are placed for a few minutes in hot soap and water; and then ladled to a trough of clean warm water. The principal end of the silk of each cocoon is drawn out by the fingers; several cocoons, thus treated, are placed in a basin, with the ends of the filaments hanging over the edge; and they are thus taken to the reeling frame when wanted. The machine consists of an iron framework, 12 feet long, 4 feet wide, and 4 feet high. At each side is a row of 30 bobbins, each with a flyer, and with a separate rotary motion. Over the 60 bobbins are 60 copper basins, containing water at 120° Fahr. Into each basin are put 6 cocoons, the filaments from which are wound off by the motion of the bobbins, to which their ends are attached. About 12 inches above each basin is a piece of wire, covered with some soft substance; the filaments pass over these wires on their way from the basins to the bobbins, to cleanse and partially dry them. By this arrangement the winding into hanks, as performed by the silk growers abroad, the winding of bobbins from the hanks, and the usual cleansing process as performed by the throwster, are entirely dispensed with: a twisted thread of silk being furnished at one operation. Threads of different thicknesses may thus be produced, simply by increasing the number of cocoons in each basin. One girl can attend to the cocoons in 30 basins. Whenever a cocoon breaks or comes to an end, a new fastening is instantly made. By an adjustment of the bobbins and flyers, any amount of twist can be imparted to the thread, according to the purpose for which it is intended. The regularity of the movements leads to the production of a thread more free from knots than the ordinary reeled silk. There is no reeling, no hank; the silk is spun at once from the cocoons. The bobbins rotate 3000 times per minute. The principle of the cotton spindle and flyer being adopted, there is a power of adapting the apparatus to the production of many different kinds of thread; it can either be stopped at the *tram* stage, or advanced to that of *organzine*—terms that will be explained presently. There is said to be a more complete extraction of the silk from the cocoons, a greater regularity in the thread, a thorough extraction of lumps and knots, an avoidance of waste, and a saving in wages. These machines are gradually coming into use in Lancashire and on the continent; but there has not yet been organised an extensive importation of cocoons into England—without which, of course, the machines cannot work.

Silk Throwing and Weaving.—Except under the system just described, silk is imported in hanks, not in the cocoons. The silk in the hanks has simply been reeled, without regular twisting. In China and India the silk is reeled very unequally; there may be as few as five, or as many as fifteen filaments in each thread, without any regard to uniformity. Italian silk is better reeled. In the *throwing* mills, situated chiefly in Lancashire and Derbyshire, the silk is doubled, twisted, and hardened. John and Thomas Lambe introduced the art from Italy early in the last century. The silk is made into *dumb singles*, for weaving into gauze and other light fabrics; into *thrown singles*, which, when wound, cleaned, and thrown, is used for weaving into ribbons and common silks; into *tram*, which is doubled as well as thrown, and is used for the weft of the best kinds of goods; into *organzine*, used for the warp; and into *sewing silk*, which is the thickest and best of all. These kinds are produced by the processes of *winding*, *cleaning*, *doubling*, and *twisting*, carried to a greater or less extent. The *winding* is the transference of the silk to bobbins. The hanks are opened, and put upon light frames called *swifts*; and while these are rotating, a series of rotating bobbins draw off the silk from the swifts. *Fig.* 3 shows one form of apparatus for effecting this transfer. The *cleaning* is effected by passing the filament through a cleft in a piece of steel, whereby impurities and irregularities are removed. The *doubling* and *twisting* are processes in which two or more threads are twisted round each other; the machinery for effecting this is very varied; but a reference to Cotton Manufacture will afford means for judging of the general principle, although the details are different. *Fig.* 4 will illustrate the action of one form of twisting or throwing machine. When silk is required to be made very thick, strong, and densely twisted, it is sometimes twisted in the manner of rope, in a long alley or avenue (*fig.* 5). Silk *spinning* is comparatively a modern process. It is a mode of using up floss silk, and any waste that may result from the other processes. However unfitted silk may be to be thrown and twisted in the usual way, it may be spun into a continuous thread by carding, drawing, roving, and spinning, almost in the same manner as cotton. The thread produced is of inferior character, and is used for the cheaper kinds of goods.

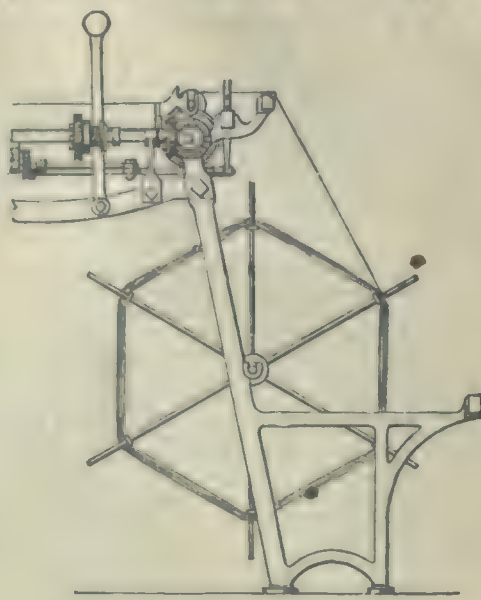


Fig. 3.—Silk Engine or Swift.

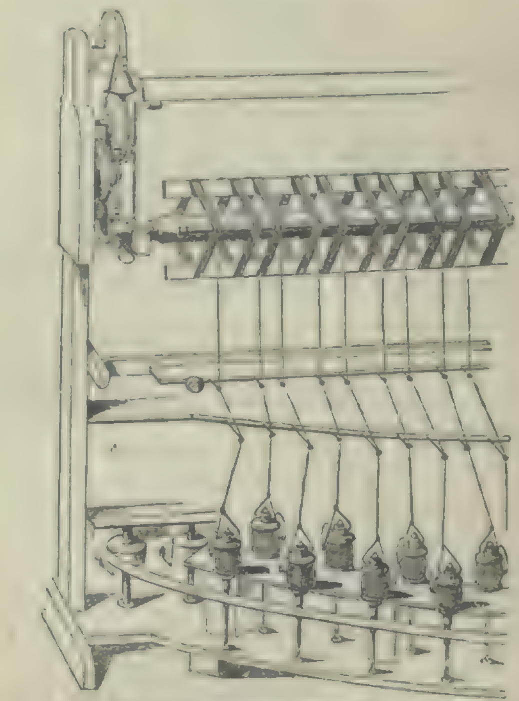


Fig. 4.—Twisting or Throwing Machine.

Of the subsequent processes in the silk manufacture, little need be said here. A reference to the articles Crape, Dyeing, Embroidery, Gauze, Jacquard Apparatus, Ribbon, and Weaving, will supply the requisite details. Brocade and damask, the most sumptuous articles of silk manufacture a century ago, are now comparatively unknown. Persian, sarsnet, gros-de-Naples, ducapes, satin, and levantines, are the names given to plain silks, which vary from one another only in texture, quality, or softness. Satin derives its lustre from the great proportion of the threads of the warp being left visible, and the piece being afterwards passed over heated cylinders. Other varieties of silk goods are produced by mechanical arrangements in the loom, such as using different shuttles with threads of various quality, &c. The pile which constitutes the peculiarity of velvet is produced by the insertion of short pieces of silk thread, which cover the surface so entirely as to conceal the interlacing of the warp and woof. The process of weaving velvet is slow, and it is paid for at several times the rate of plain silks. There are several sorts of goods in which silk is employed with woollen materials, such as poplins and bombazines. The Chinese make a species of washing silk, called at Canton ponge, which becomes more soft as it is longer used. Their crapes have never yet been perfectly imitated; and they particularly excel in the production of damasks and flowered satins.

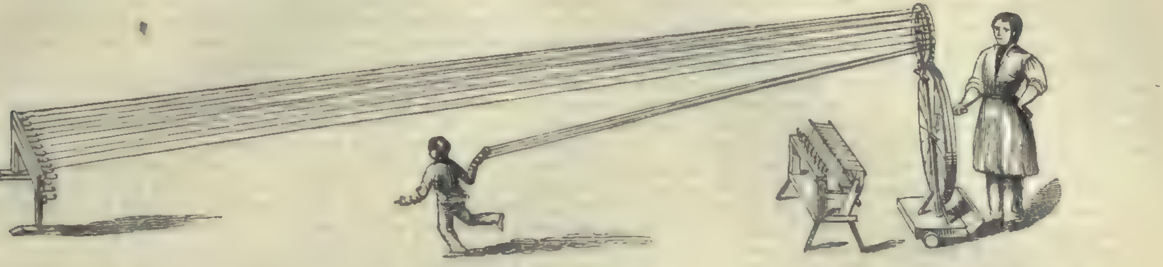


Fig 5.—Silk Spinning by hand.

Silk Trade.—The making of ribbons and small articles in silk long preceded in England that of broad silk. The trade was principally in the hands of women; and, like a sickly plant of foreign growth, it appears to have constantly demanded props and support. Repeated statutes and orders were made, discouraging the use of silk goods from abroad. An act passed in the reign of Edward IV. contained a sort of apology, which, if good for anything, made the prohibition unnecessary. The act states that not only were the artificers, men and women "greatly impoverished, hindered of their worldly increase and daily living, by these wares and chaffres being brought in fully wrought and ready for sale by strangers, the king's enemies, and other," but that "the greatest part in substance was deceitful, and nothing worth in regard of any man's occupation and profit." The law against the importation of ribbons, &c. was renewed at successive intervals until the 19 Henry VII., when it was made perpetual. Foreign ribbons notwithstanding still made their way over. The silk-throwsters were incorporated by a charter obtained 5 Charles I., about ten years after the establishment of the broad-silk manufacture in the reign of James I.: the silk-weavers were already included in the great company of weavers. Towards the end of the reign of Charles II., the silk manufacture, which had hitherto been almost confined to London, was carried into several other large towns of the kingdom by the French Protestants, who took refuge in this country, to the number, it is said, of 70,000, after the revocation of the Edict of Nantes in 1685; and amongst the rest to Coventry. The ribbon trade, of which Coventry has since become the chief seat in England, was introduced early in the last century by Mr. Bird, assisted probably by some of the French emigrants: the number of French terms still used in the manufacture proves that its origin was, in part at least, foreign. After the treaty of Utrecht, in 1713. French and Italian manufactured silks were admitted under considerable duties; but in 1765 the ribbon and other silk manufacturers procured the re-establishment of the prohibitory system, which was thenceforward maintained for sixty years, enforced by heavy penalties. With the increase of population and the greater demand for luxuries, the home market increased; but an export trade, principally to America, gradually decayed, in consequence perhaps of the heavy duties on raw and thrown silk. During the period of restriction, ribbon-weaving seems to have degenerated in this country as regards the superior branches. In 1824 the government determined to try the effect of an approach to free trade upon the silk manufacture. As a preliminary step, the duties on raw silk were reduced from 4*d.* per lb. to 3*d.*, and afterwards to 1*d.*; and on thrown, from 14*s.* 8*d.* to 7*s.* 6*d.*, and afterwards to 3*s.* 6*d.*, 2*s.*, and 1*s.* 6*d.*, according to quality; with a drawback to the amount of the duty allowed on any manufactures of silk exported, whether they were or were not made of the foreign thrown silk which had paid the duty. Two years were allowed after the lowering of these duties to prepare for the admission of foreign manufactured silk at a duty of 30 per cent. But this step was strongly opposed by the ribbon manufacturers of Coventry, who were unanimous in demanding a total prohibition of foreign ribbons; they succeeded in procuring, in 1832, the appointment of a committee of the House of Commons to inquire into the state of the silk trade. Nothing short of this (they said) could enable them to make ribbons at all. This inquiry led to no alteration in the system which the government had adopted; and subsequent remonstrances made by the same parties had a similar result.

Without tracing in detail the progress of the trade and the alterations in the duties, it will suffice to give a few figures relating to the last few years. Sir Robert Peel wholly removed the import duty on raw silk in 1845; and since that year every part of the trade has extended. The raw silk imported between 1844 and 1860, varied from 4,133,000 lbs. (in 1844) to 12,078,000 lbs. (in 1857). But the last-named year was an exceptional one, in regard to the largeness of the import; the import for the last seven years has averaged about 8,000,000 lbs. per annum. The above is *raw* silk, in the hank. The *thrown* silk, ready for the weaver, is imported in much smaller quantity, varying from 300,000 lbs. to 1,000,000 lbs. per annum. Manufactured silk goods imported are entered by the *lb.* or by the *piece*, according to their character—that is, European goods by the lb., and India goods by the piece. About 800,000 lbs. of broad silks and 400,000 lbs. of ribbons, from the continent, together with half a million pieces of India goods (Bandanas, Corahs, Choppas, Tussire cloths, Romals, and Taffetas)—have been about the average quantities within the last few years. Omitting all years but 1859, we will give the exact figures for that date:—

Raw silk, from China . . .	3,192,632	9,920,891 lbs.
" " India and Egypt .	5,805,487	
" " other countries .	922,772	
Waste, knubs, and husks		20,808 cwt.
Thrown silk, from France . .	155,872	327,462 lbs.
" " other countries .	171,590	
European blond, silk, and satin . .	305,523	987,080 lbs.
" gauze, crape, and velvet .	41,918	
" ribbons	479,106	
" plush for hats . . .	160,533	
India piece goods		843,084 pieces.

The *exports* of course do not comprise any *raw* silk. Of *thrown* silk, in the various forms of thread and yarn, the quantity exported from 1844 to 1860, varied from about 200,000 lbs. (in 1848) to 1,400,000 lbs. (in 1856). Of woven silk goods the quantity varied from 600,000 lbs. (in 1848) to 3,000,000 lbs. (in 1856). Taking one particular year (1858) as a fair average for seven recent years, we find that the computed real value of all the silk and silks imported was about 8,000,000*l.*; and that the declared value of the silk and silks exported was about 2,000,000*l.* Raw silk is imported duty free; manufactured goods pay an import duty, which in 1858 amounted to about 900,000*l.* By the new commercial treaty with France, England has given up about 300,000*l.* a year, that having been the produce of duties laid on French silk and silk goods.

Without going into details, it may suffice to state that the quantity of silk imported in 1860, whether raw, waste, or thrown, was less than in 1859; but greater in reference to manufactured silk. The export of silk goods woven in England was smaller in 1860 than in 1859; but of silk-thread and yarn, it was higher.

Mr. Winkworth, a Spitalfields manufacturer, estimated in 1857 that 50 millions sterling are sunk in the United Kingdom in the silk manufacture, and that 1,000,000 persons are supported by it. For the number of mills, see FACTORIES.

SILVER (Ag., from the Latin *argentum*). This metal has been known from the earliest times, frequent mention being made of it in the writings of Moses. Occurring naturally in the metallic state, though not so frequently as to render it common, and being easily worked, it must, no doubt, have been one of the first discovered metals. The alchemists and astrologers supposed it to have some mysterious connection with the moon, gave it the sign ☽, and called it *Diana* or *Luna*. They also seem to have been acquainted with chloride of silver (horn-silver) and nitrate of silver (lunar caustic).

Next to the free metal itself, the sulphide is the most important ore of silver. It is usually associated with sulphide of lead; indeed *galena* lead-ore nearly always contains silver, which is separated as described under LEAD, MANUFACTURE OF. The ore is roasted to expel sulphur, smelted with charcoal, and the argentiferous lead submitted to *cupellation* [ASSAYING], by which the lead, becoming oxidised, is partly volatilised, partly raked off the surface, and partly sinks into the cupel, leaving pure silver in the liquid state.

Another process for the extraction of silver from its ores is termed *amalgamation*, from the fact that the metal, after the ore has been roasted and the silver reduced by scrap iron, is dissolved out by mercury; the separated amalgam is afterwards submitted to distillation, when the mercury volatilises and the silver is left behind. [AMALGAM.] The processes, of which the final step is amalgamation, are many; the ores at different places, being associated with various matters, require different modifications of treatment. One metallurgist, Augustin, dispenses with the use of mercury altogether. Ziervogel at once obtains sulphate of silver by roasting the ore at a particular temperature, and precipitates the metal therefrom by copper.

Silver is almost pure white, having only the faintest tinge of red. In the native state it sometimes occurs crystallised in cubes or octohedra. It is moderately hard, elastic, and very ductile and malleable; one grain may be drawn into 400 feet of wire, and the thinnest silver-foil, or leaf-silver, has a thickness of only [illegible] of an inch. Silver melts at a bright red heat, and by repeated fusions becomes quite brittle. It volatilises in the luminous arc of a powerful electric current, yielding a beautiful green-coloured vapour. Of all metals, silver is, perhaps, the best conductor of heat and electricity. It does not oxidise at ordinary temperatures, but when melted has the property of absorbing many times its bulk of oxygen, which, however, is given out again at the moment of solidification. Though silver does not rust in the air, it rapidly tarnishes, owing to the formation of a thin film of sulphide of silver: this occurs more quickly in urban than in rural districts, sulphur in the form of sulphuretted hydrogen being far more abundant in the atmosphere of the former than in that of the latter localities.

Silver is not readily acted upon by alkalies, hence it is of peculiar value in the manufacture of vessels in which alkaline fusions have to be made. Common salt, especially in the melted state, is slowly decomposed by silver, soda being formed, from absorption of oxygen, while liberated chlorine attacks the metal. Boiling sulphuric acid oxidises silver; hydrochloric acid acts but slightly upon it; aqua regia attacks it readily; but its best solvent is nitric acid.

Perfectly pure silver may be obtained by dissolving the commercial metal in nitric acid, precipitating with hydrochloric acid, and then fusing the well-washed chloride with half its weight of dried carbonate of soda. In the place of carbonate of soda, carbonate of lime and charcoal are sometimes employed. Chloride of silver may also be reduced by placing it in contact with zinc and dilute sulphuric acid.

The equivalent of silver is 108.

Silver and *oxygen* form three compounds:—

1. Suboxide of silver	Ag_2O
2. Protoxide of silver	AgO
3. Peroxide of silver	AgO_2

1. *Suboxide of silver* (Ag_2O). Citrate of silver is heated to 212° in a current of hydrogen; on dissolving the resulting mass in water, and adding an alkali, the suboxide is precipitated as a black powder. When dry, it acquires metallic lustre under the burnisher.

Molybdate of suboxide of silver ($Ag_2O, 2MoO_3$). Wöhler forms this salt by passing hydrogen gas through an ammoniacal solution of molybdate of silver at 90°. It is a heavy brilliant black powder, in which occur regular octohedra. The *tungstate* of the suboxide is made in the same manner as, and much resembles, the molybdate. *Chromate* of suboxide of silver is black and amorphous.

2. *Protoxide of silver* (AgO). A brown *hydrated oxide* of silver is thrown down when solution of potash, soda, baryta, or lime is added to solution of nitrate of silver. It becomes anhydrous when heated to 140° Fahr., and is reduced to the metallic state by increased heat, by light, hydrogen, or almost any deoxidising agent. It is a powerful base, forming salts, the chief of which are presently described.

3. *Peroxide of silver* (AgO_2) occurs in dark gray acicular crystals when a solution of nitrate of silver is electrolysed. It accumulates on the positive pole, is a conductor of the electric current, but is very unstable.

Sulphide of silver. (AgS). The elements sulphur and silver have a great affinity for each other; the compound produced by their union occurs native in large quantities. [SILVER, in NAT. HIST. DIV.] Sulphide of silver may be formed artificially by passing a stream of sulphuretted hydrogen gas through a solution containing silver, or on adding a soluble sulphide to the silver solution, or, still more simply, by heating together sulphur and silver in their equivalent proportions.

Sulphide of silver readily fuses and cools to a dark-gray, crystalline mass, that is somewhat soft and malleable. It is decomposed and dissolved when heated with concentrated sulphuric or nitric acids, and is also readily attacked by strong hydrochloric acid. Potash, soda, iron, copper, or lead reduce it, by the aid of heat, to the metallic state.

Chlorine and silver form two compounds, namely:—

1. Subchloride of silver	Ag_2Cl
2. Protochloride of silver	$AgCl$

1. *Subchloride of Silver* (Ag_2Cl). When silver leaf is digested in solution of chloride of copper, or of perchloride of iron, black scales of subchloride of silver are produced. Nitric acid does not affect them, but ammonia resolves them into chloride of silver and metallic silver.

2. *Protochloride of Silver* ($AgCl$), *Chloride of Silver*, or, *Horn Silver*, is found native. [SILVER, in NAT. HIST. DIV.] It falls as a white, curd-like precipitate when hydrochloric acid or any soluble chloride is added to an aqueous solution of silver salt.

Chloride of silver is insoluble in water or dilute acids, and is only very slightly acted on by strong nitric or hydrochloric acids. It is somewhat more soluble in solutions of chlorides of alkalies or of alkaline earths, and is freely dissolved in solution of ammonia. It fuses when heated to about 500° Fahr., and on cooling forms a semi-transparent horn-like mass. It is partially reduced to the state of sub-chloride on exposure to light. A current of hydrogen removes the whole of the chlorine from heated chloride of silver; zinc, iron, and some other metals also reduce it to the metallic state. Chloride of silver forms double salts with alkaline cyanides, sulphites, and hyposulphites; the solutions of the last-named have a most intensely sweet taste, exceeding even that of sugar.

Bromide of Silver ($AgBr$) occurs native. It may be prepared artificially by precipitating nitrate of silver by bromide of potassium. It much resembles chloride of silver, but is less soluble in ammonia, and has moreover a yellow colour.

Iodide of Silver (AgI). This compound occurs native also. It falls as a yellow precipitate when an alkaline iodide is added to solution of nitrate of silver. It is insoluble in acids and nearly so in ammonia, but is very soluble in solution of iodide of potassium or hyposulphite of soda.

Sulphate of Silver ($AgOSO_3$). When silver is boiled in strong sulphuric acid, sulphate of silver is formed according to the following equation:—

$$\underbrace{Ag}_{\text{Silver.}} + \underbrace{2(HO, SO_3)}_{\text{Sulphuric acid.}} = \underbrace{AgO, SO_3}_{\text{Sulphate of silver.}} + \underbrace{SO_2}_{\text{Sulphurous acid.}} + \underbrace{2HO}_{\text{Water.}}$$

It is soluble in excess of the acid, but requires ninety parts of water to dissolve it.

Nitrate of Silver (AgO, NO_5). This salt, now so largely used in photography, and, when fused and cast into cylinders as an escharotic, under the name of *lunar caustic*, by surgeons, is formed on dissolving silver in strong nitric acid. By evaporation of the solution, colourless, transparent right rhombic crystals are deposited. It has an unpleasant bitter metallic taste, is soluble in water or alcohol, and is not decomposed by exposure to light unless in contact with organic matter. Solution of ammonio-nitrate of silver is formed by adding ammonia to nitrate of silver until the resulting precipitate is nearly all redissolved.

The following are the principal remaining salts of silver that are of interest. They are produced by the ordinary process of double decomposition.

The *triphosphate* ($3AgO, PO_5$) is of yellow colour, alterable by the action of light, readily soluble in excess of nitric acid or of ammonia.

The *pyrophosphate* ($2AgO, PO_5$) is white and easily fusible.

The *metaphosphate* (AgO, PO_5) occurs as a gelatinous mass, soluble in excess of nitrate of silver. The *carbonate* (AgO, CO_2) is at first white, afterwards pale yellow. The *borate* (AgO, BO_3) forms white flakes which turn violet on exposure to light. The *iodate* (AgO, IO_5) is white, and crystallises from ammonia in brilliant little rectangular prisms. The *chlorate* is soluble in water, and crystallises in white, opaque, four-sided prisms. The *monochromate* (AgO, CrO_3) is of a greenish-brown colour by reflected light and deep red by transmitted light. The *bichromate* ($AgO, 2CrO_3$) is a purple-red crystalline precipitate. The *arseniate* ($3AgO, AsO_5$) is a dark brick-red precipitate, soluble in ammonia and in carbonate of ammonia.

For the salts which silver forms with organic acids, see the articles on those acids.

Tests for Silver. The production of the white curdy chloride on the addition of hydrochloric acid, the precipitate being insoluble in hot nitric acid but readily soluble in ammonia, forms the characteristic test for silver salts. Reduction on charcoal in the blow-pipe flame, a black precipitate by sulphuretted hydrogen, and a yellow one on the addition of an alkaline iodide, are confirmatory tests.

Estimation of Silver. This is accomplished as described under ASSAYING, or in the state of well-washed and fused chloride, 100 parts of which contain 75·27 of metal.

SILVER, *Medical Properties of.* In a purely metallic state silver has no action on the animal frame, and the only salt much used is the nitrate, termed also *lunar caustic.* This is always fused in proper moulds, from which it is turned out in the form of cylinders, about three inches long, and the eighth of an inch in diameter. They are at first white, but quickly become of a dark gray or black colour, from combining with organic matter in the air. To prevent this the cylinders are generally wrapped up in blue paper. When nitrate of silver is brought in contact with any part of the human frame, it causes first a white mark, which gradually changes to blue, purple, and at last to black. This occurs more rapidly if moisture be present; and is owing to a chemical combination of the metal with the albumen and fibrin of the animal tissues. If the part be wetted, and the caustic applied several times at short intervals, vesication results. Nitrate of silver acts therefore locally as an *irritant* and *corrosive.* When taken internally in small doses for a considerable time, such as six or twelve months, it is absorbed and deposited in various parts of the body, and when it is deposited in the *rete mucosum* of the skin it causes discolorations, which in most cases prove permanent. It has been sometimes employed with success in the treatment of epilepsy, chorea, and some forms of *angina pectoris,* as well as morbid sensibility of the stomach. Larger doses can be borne when it is administered in the form of pill than in solution. The pills should be made with mucilage and sugar, but not with bread-crumb, as the common salt, or chloride of sodium, decomposes the nitrate and renders it inert. In cases of poisoning by nitrate of silver, common salt is a ready and effectual remedy: also milk. The liability of nitrate of silver to produce discolorations of the skin in persons taking it internally constitutes a serious objection to its employment, and there appears little necessity for giving it, since any case of epilepsy likely to be benefited by it will generally receive equal good from the use of *oxide of zinc*, without the risk of stains or other inconvenience.

The external employment of this agent is not liable to any objection when used cautiously, while its advantages are very great. It is the most powerful *direct antiphlogistic* agent known. All subacute inflammations in any part to which it can be immediately applied will subside under its influence. In inflammations not merely of the skin, but of mucous membranes when they occur in parts which are accessible, its influence is great and speedily manifested. Many of the cases of croup which in an advanced stage are unmanageable, begin in the back part of the throat (fauces), and if these parts are freely touched with a pencil dipped in a strong solution of nitrate of silver, the farther downward progress of the inflammation may be arrested. Similar benefit attends its use in *diphtheria*: for this a very strong solution in nitric ether is best. The same treatment is applicable to the erythematous inflammation which frequently begins either externally, and spreads through the mouth or nose to the fauces, and thence down the œsophagus, or originates in the fauces, leading to very serious results. Erysipelatous inflammation occurring in any part of the body may be effectually limited by nitrate of silver. For this purpose a complete circle should be formed round the inflamed part, but on the sound skin. For this case the solid cylinder, moistened at the end, is best. The circle must be perfect, or the morbid action may extend, escaping at the smallest breach. Chronic inflammation, and even ulceration, of the eyes, may be removed by nitrate of silver applied in different forms. Old indolent ulcers are stimulated to a healthy action by its use; and many cutaneous diseases removed by it. Recent burns have the severe pain often very much mitigated by it; but it must not in any of these cases be applied to too large a surface at once, as ill effects have followed such a practice. To specify all the uses of nitrate of silver would be impossible here, but one more deserves to be extensively known. It is the best application to chilblains, especially at first; but even after they break, it disposes them to heal.

When a solution of nitrate of silver is made, distilled water should invariably be used. The neglect of this rule causes many of the solutions applied to the eye to be not only useless, but hurtful. Oxide of silver has been strongly recommended as an antispasmodic, and not liable to the objections which attach to the nitrate. In preparing medicines with oxide of silver, care must be taken not to combine it with articles such as ammonia, lest an explosive compound should result.

SILVER WORKING. Silver-ores are found chiefly in veins which traverse the primary and the older of the secondary stratified rocks, but especially the former; and also the unstratified rocks, such as granite and porphyry, which are associated with the above. Some of the richest mines in South America are situated in primary strata; also in limestone and in grauwacke, and still more in secondary strata. In some of the mines of Peru, and in those of Kongsberg in Norway and Freiburg in Saxony, silver has been discovered in masses weighing from 100 to 800 lbs. In the mines of Europe the veins are numerous and slender; in some of the mines in the Harz Mountains and in the Hungarian mines the veins occur in a small number of spots, and are of considerable dimensions. In three of the richest districts of Mexico there is only one principal vein, which is worked in different places. One of these veins, in the district of Guanaxuato, is from 130 to 148 feet wide, and it has been traced and worked to an extent of nearly eight miles.

The average richness of all the ores in Mexico is from 3 to 4 ounces per quintal of 102 lbs. In one of the Mexican mines a working of 100 feet in length yielded in six months 432,274 lbs. troy of silver, equal in value to upwards of 1,000,000*l*. In Chili some of the mines yield only 8 oz. in 5000 lbs. of ore; but in the rich mine of Copiapo, discovered in 1832, the ore frequently contains 60 or 70 per cent. of silver. The average produce of the mines in Saxony is from 3 to 4 ounces in the quintal. The lead mines of Craven in Yorkshire contained 230 ounces of silver per ton; and those of Cardiganshire, worked in the reign of Charles I., yielded 80 ounces. The average proportion of the lead-mines of the north of England is 12 ounces per ton; but even when the proportion of silver is much less than this, it has been found profitable to separate it. The pure metal is separated from the ore by various processes; by mechanical division, roastings to separate the sulphur and other volatile matter, and melting at different stages of purification, with the addition of fluxes of various sorts. Refining is performed by amalgamation with quicksilver, the two metals being afterwards separated by distilling off the quicksilver. [Amalgam; Lead Manufacture, col. 149.]

When silver is issued for coin, it is always alloyed with copper; the maximum of hardness is produced by one-fifth of copper. One lb. of standard silver of the English coinage contains 11 oz. 2 dwts. of pure silver and 18 dwts. alloy, or 925 parts of pure silver in 1000 parts

of standard silver. [Money.] For purposes connected with the manufacture of various articles of use and ornament the alloy is greater. At Birmingham rolled sheets are made which do not contain more than 3 or 4 dwts. of silver to each lb. of the inferior metal. Silver forms by far the largest proportion of the value of domestic utensils in which either of the two precious metals is used. It has also been suggested that electro-plating with silver might be applied to the interior of leaden pipes, when used for domestic purposes.

The rolling of silver in contact with the inferior metals is performed by powerful flatting-mills. A bar of copper is made quite smooth and clean on one of its surfaces, it is then sprinkled over with glass of borax; a plate of fine silver is laid upon it, and the two are carefully bound together by wire. The mass is then exposed to a full red heat, which melts the borax and causes the silver to adhere to the copper. The ingot is now passed through a rolling-press and formed into a plate, both the silver and copper extending uniformly during the whole process, at the conclusion of which they are inseparably joined.

Mr. M'Culloch, on the authority of Mr. Birkmyre, gives an estimate of the quantity of silver produced in the two years next before, and the two years next after, the discovery of gold in California. According to this authority, in the year 1846 there was procured in America silver to the value of 5,261,619*l*., and in the other parts of the world 1,254,306*l*.; while in 1850 these values were raised to 7,259,824*l*. and 1,528,592*l*., respectively. It is interesting to note that, in 1857, more than 1,300,000 ounces of silver were obtained by refining lead in the lead-smelting works of the United Kingdom, of which about half a million ounces were from British lead.

It may suffice here to refer to several foregoing articles, for further information concerning the working of silver; such as Bullion; Gold Lace Manufacture; Mint; Money; Plate and Plating.

SILVER, GERMAN. [Copper; Tutenag.]

SILVERING, as a handicraft, is not always an example of silver-working, as the name would seem to imply; for in silvering looking-glass, no silver whatever is used, in the ordinary methods.

One mode of silvering, first adopted at Sheffield, is that of rubbing an amalgam of silver and mercury on the surface of any article of copper; by the application of heat the mercury is driven off; the silver, remaining behind, adheres firmly to the copper, and is susceptible of receiving a high polish. This is, chemically, analogous to the process of metal-gilding, or so-called "water-gilding," described under Gilding. The details, in the same article, concerning the application of leaf-gold, will nearly apply also to that of leaf-silver in the silvering of articles made of wood.

In an ordinary looking-glass, the reflection is derived from a film of mercury or quicksilver, in contact with the hinder surface of the glass, and fixed by amalgamating with a sheet of tin-foil. Silvering is here not a correct term, for there is no silver employed. The process is nevertheless a highly curious one. In the first place, a large sheet of tin-foil is unrolled, and laid down on a perfectly flat and very smooth stone table. Liquid mercury is poured on the foil, from the iron bottles in which it is imported, and made to float over the entire surface. The glass, made perfectly clean, is laid upon the mercury with a peculiar sliding movement, which suffices to remove the slight film of oxide which soon forms upon the surface, and also any air bubbles. The glass is then entirely covered with heavy leaden weights, which could not be done with safety unless the glass and the stone were perfectly flat. After remaining a day or two in this state, with the stone slightly inclined, it is found that all the superfluous mercury has been pressed out from between the glass and the foil; and, moreover, that the mercury has chemically combined with the foil, in such a way that both adhere firmly to the back of the glass.

In Mr. Drayton's process, nitrate of silver is combined with spirit and certain liquids, and is poured on the clean surface of the glass: a border of putty or some other substance being laid round the glass to retain the liquid. After remaining thus a few hours, the liquid is poured off, and a sediment of silver is found to be left adhering to the glass. This sediment or film is secured in its place by a varnish of bees' wax and tallow.

In Kidd's embroidered glass, the peculiarity of the process is that the patterns have the appearance of being in relief, or embossed on the exterior surface, and illuminated in frosted and burnished silver, whereas the whole of the processes are effected on the under surface.

Dr. Thomson's silvered vessels display great brilliancy and beauty. Glass vessels of any shape, and made of glass of any colour, are silvered within in such a way as to yield a reflection of great lustre. Some of the specimens, in which green and ruby glass are thus silvered, produce an effect which can hardly be paralleled in any other manufacture. The surface is often richly cut and diversified, and the silvering may be made to appear at any spots selected by the workman. The silvering agent is one of the salts or compounds of silver, as in Drayton's process; but arrangements of an intricate kind are requisite to the due production of the required effects.

Dr. Faraday has described at the Royal Institution a mode of silvering introduced by M. Petitjean. A solution of oxide of silver, ammonia, nitric acid, and muriatic acid is employed. A cast-iron table-box is provided, with water within and gas underneath. The sheet of glass to be silvered is laid upon the iron plate and heated to 140° Fahr. by gas flames acting through or on the water. The solution is poured on the glass, together with a little polishing-powder. When well floated, the solution is rolled with an india-rubber roller to expel all air-bubbles. Then more solution is poured on, and more heat applied, until a precipitate of pure silver is deposited on the glass, which takes place in about a quarter of an hour. The surplus liquid being poured off, and the silver washed, it is found to present a beautiful reflecting surface. No mercury being here employed, the process is less harmful than that usually adopted.

SIMARUBA BARK is obtained from the root of the *Simaruba amara*, Aublet. *S. officinalis*, Dec. It is a native of Guyana, and also of Jamaica (unless this latter be a distinct species), and the more southern of the United States.

It is intensely bitter, and yields an infusion more bitter than the decoction. The infusion made with cold water is best. It may be used as an emetic or tonic, in fever and dysentery; also, against worms. If the wood be used in cooking, the viands acquire an intense bitterness. The *Simarouba versicolor* (Aug. St. Hilaire), a native of Brazil, has similar properties, but its internal use causes stupor and other narcotic symptoms. This effect might be avoided by making the infusion with *cold water*, as in the case of quassia. [QUASSIA.]

SIMILAR, SIMILAR FIGURES (Geometry). Similarity, resemblance, or likeness, means sameness in some, if not in all, particulars. In geometry, the word refers to a sameness of one particular kind. The two most important notions which the view of a figure will give are those of *size* and *shape*, ideas which have no connection whatsoever with each other. Figures of different sizes may have the same shape, and figures of different shapes may have the same size. In the latter case they are called by Euclid *equal*, in the former *similar* (similar figures, *δμοια σχήματα*). The first term [EQUAL; RELATION], in Euclid's first use of it, includes united sameness both of size and shape; but he soon drops the former notion, and, reserving equal to signify sameness of size only, introduces the word similar to denote sameness of form: so that the equality of the fundamental definition is the subsequent combined equality and similarity of the sixth book.

Similarity of form, or, as we shall now technically say, similarity, is a conception which is better defined by things than by words; being in fact one of our fundamental ideas of figure. A drawing, a map, a model, severally appeal to a known idea of similarity, derived from, it may be, or at least nourished by, the constant occurrence in nature and art of objects which have a general, though not a perfectly mathematical, similarity. The rudest nations understand a picture or a map almost instantly. It is not necessary to do more in the way of definition, and we must proceed to point out the mathematical tests of similarity. We may observe indeed that errors or monstrosities of size are always more bearable than those of form, so much more do our conceptions of objects depend upon form than upon size. A painter may be obliged to diminish the size of the minor parts of his picture a little, to give room for the more important objects: but no one ever thought of making a change of form, however slight, in one object, for the sake of its effect on any other. The giant of Rabelais, with whole nations carrying on the business of life inside his mouth, is not so monstrous as it would have been to take the ground on which a nation might dwell, England, France, or Spain, invest it with the intellect and habits of a human being, and make it move, talk, and reason: the more tasteful fiction of Swift is not only bearable and conceivable, but has actually made many a simple person think it was meant to be taken as a true history.

Granting then a perfect notion of similarity, we now ask in what way it is to be ascertained whether two figures are similar or not. To simplify the question, let them be plane figures, say two maps of England of different sizes, but made on the same projection. It is obvious, in the first place, that the lines of one figure must not only be related to one another in length in the same manner as in the other, but also in position. Let us drop for the present all the curved lines of the coast, &c., and consider only the dots which represent the towns. Join every such pair of dots by straight lines: then it is plain that similarity of form requires that any two lines in the first should not only be in the same proportion, as to length, with the two corresponding lines in the second, but that the first pair should incline at the same angle to each other as the second. Thus, if L Y be the line which joins London and York, and F C that which joins Falmouth and Chester, it is requisite that L Y should be to F C in the same proportion in the one map that it is in the other; and if F C produced meet L Y produced in O, the angle C O Y in one map must be the same as in the other. Hence, if there should be 100 towns, which are therefore joined two and two by 4950 straight lines, giving about 12 millions and a quarter of pairs of lines, it is clear that we must have the means of verifying 12¼ millions of proportions, and as many angular agreements. But if it be only assumed that similarity is a possible thing, it is easily shown that this large number is reducible to twice 98. Let it be granted that *l y* on the smaller map is to represent L Y on the larger. Lay down *f* and *c* in their proper places on the smaller map, each with reference to *l* and *y*, by comparison with the larger map: then *f* and *c* are in their proper places with reference to each other. For if not, one of them at least must be altered, which would disturb the correctness of it with respect to *l* and *y*. Either then there is no such thing as perfect similarity, or else it may be entirely obtained by comparison with *l* and *y* only.

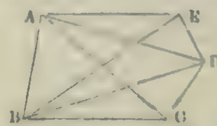
We have hitherto supposed that both circumstances must be looked to; proper lengths and proper angles; truth of linear proportion and truth of relative direction. But it is one of the first things which the student of geometry learns (in reference to this subject), that the attainment of correctness in either secures that of the other. If the smaller map be made true in *all* its relative lengths, it must be true in all its directions; if it be made true in *all* its directions, it must be true in all its relative lengths. The foundation of this simplifying theorem rests on three propositions of the sixth book of Euclid, as follows:—

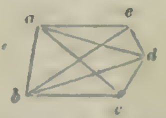
1. The angles of a triangle (any two, of course) alone are enough to determine its form: or, as Euclid would express it, two triangles which have two angles of the one equal to two angles of the other, each to each, have the third angles equal, and all the sides of one in the same proportion to the corresponding sides of the other.

2. The proportions of the sides of a triangle (those of two of them to the third) are alone enough to determine its form, or if two triangles have the ratios of two sides to the third in one the same as the corresponding ratios in the other, the angles of the one are severally the same as those of the other.

3. One angle and the proportion of the containing sides are sufficient to determine the form of a triangle: or, if two triangles have one angle of the first equal to one of the second, and the sides about those angles proportional, the remaining angles are equal, each to each, and the sides about equal angles are proportional.

From these propositions it is easy to show the truth of all that has been asserted about the conditions of similarity, and the result is, that any number of points are placed similarly with any other number of points, when, any two being taken in the first, and the corresponding two in the second, say A, B, and *a*, *b*, any third point C of the first gives a triangle A B C, which is related to the corresponding triangle *a b c* of the second, in the manner described in either of the three preceding propositions. For instance, let there be five points in each figure:

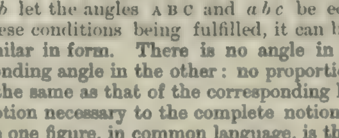


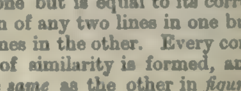


In the triangles B A E and *b a e*, let the angles A E B and E B A be severally equal to *a e b* and *e b a*. In the triangles A D B and *a d b* let D A : A B : : *d a* : *a b*, and D B : B A : : *d b* : *b a*. In the triangles A C B and *a c b* let the angles A B C and *a b c* be equal, and A B : B C : : *a b* : *b c*. These conditions being fulfilled, it can be shown that the figures are similar in form. There is no angle in one but is equal to its corresponding angle in the other: no proportion of any two lines in one but is the same as that of the corresponding lines in the other. Every conception necessary to the complete notion of similarity is formed, and the one figure, in common language, is the *same* as the other in *figure*, but perhaps on a different scale.

The number of ways in which the conditions of similarity can be expressed might be varied almost without limit; if there be n points, they are twice ($n-2$) in number. It would be most natural to take either a sufficient number of ratios, or else of angles: perhaps the latter would be best. Euclid confines himself to neither, in which he is guided by the following consideration:—He uses only salient or convex figures, and his lengths, or sides, are only those lines which form the external contour. The internal lines or diagonals he rarely considers, except in the four-sided figure. He lays it down as the definition of similarity, that all the angles of the one figure (meaning only angles made by the sides of the contour) are equal to those of the other, each to each, and that the sides about those angles are proportional. This gives $2n$ conditions in an n-sided figure, and consequently four redundancies, two of which are easily detected. In the above pentagons, for instance, if the angles at A, E, D, C, be severally equal to these at *a*, *e*, *d*, *c*, there is no occasion to say that that at B must be equal to that at *b*, for it is a necessary consequence: also, if B A : A E : : *b a* : *a e*, and so on up to D C : C B : : *d c* : *c b*, there is no occasion to lay it down as a condition that C B : B A : : *c b* : *b a*, for it is again a consequence. These points being noted, the definition of Euclid is admirably adapted for his object, which is, in this as in every other case, to proceed straight to the establishment of his propositions, without casting one thought upon the connection of his preliminaries with natural geometry.

Let us now suppose two similar curvilinear figures, and to simplify the question, take two arcs A B and *a b*. Having already detected the test of similarity of position with reference to any number of points, it





will be easy to settle the conditions under which the arc A B is altogether similar to *a b*. By hypothesis, A and B are the points corresponding to *a* and *b*. Join A, B, and *a*, *b*; and in the arc A B take any point P. Make the angle bap equal to BAP, and abp equal to ABP; and let ap and bp meet in p. Then, if the curves be similar, p must be on the arc ab; for every point on AB is to have a corresponding point on ab. Hence the definition of similarity is as follows:—Two curves are similar when for every polygon which can be inscribed in the first, a similar polygon can be inscribed in the second.

It is easily shown that if on two lines, A and a, be described a first pair of polygons, P and p, and a second pair, Q and q, the proportion of the first and second pairs is the same, or $P : p :: Q : q$. The simplest similar polygons are squares; consequently, any similar polygons described on A and a are to one another in the proportion of the squares on A and a. This is also true if for the polygons we substitute similar curves; and it must be proved by the method of exhaustions [GEOMETRY], or by the theory of limits applied to the proposition, that any curve may be approached in magnitude by a polygon within any degree of nearness.

The theory of similar solids resembles that of similar polygons, but it is necessary to commence with three points instead of two. Let A, B, C, and a, b, c, be two sets of three points each, and let the triangles ABC and abc be similar: let them also be placed so that the sides of one are parallel to those of the other. If then any number of similar pyramids be described on ABC and abc, the vertices of these pyramids will be the corners of similar solids. If P and p be the vertices of one pair, then the pyramids $PABC$ and $pabc$ are similar if the vertices P and p be on the same side of ABC and abc [SYMMETRY], and one of the triangles, say PAB, be similar to its corresponding triangle pab, and so placed that the angle of the planes PAB and CAB is the same as that of the planes pab and cab. The simplest similar solids are cubes; and any similar solids described on two straight lines are in the same proportion as the cubes on those lines. Similar curve surfaces are those which are such that every solid which can be inscribed in one has another similar to it, capable of being inscribed in the other.

It is worthy of notice that the great contested element of geometry [PARALLELS] would lose that character if it were agreed that the notion of form being independent of size is as necessary as that of two straight lines being incapable of enclosing a space; so that whatever form can exist of any one size, a similar form must exist of every other. There can be no question that this universal idea of similarity involves as much as this, and no more; that in the passage from one size to another, all lines alter their lengths in the same proportion, and all angles remain the same. It is the subsequent mathematical treatment of these conditions which first points out that either of them follows from the other. If the whole of this notion be admissible, so in any thing less; that is, the admission implies it to be granted that whatever figure may be described upon any one line, another figure having the same angles may be described upon any other line. If then we take a triangle ABC, and any other line ab, there can be drawn upon ab a triangle having angles equal to those of ABC. This can only be done by drawing two lines from a and b, making angles with ab equal to BAC and ABC. These two lines must then meet in some point c, and the angle acb will be equal to ACB. If then two triangles have two angles of one equal to two angles of the other, each to each, the third angle of the one must be equal to the third angle of the other; and this much being established, it is well known that the ordinary theory of parallels follows. The preceding assumption is not without resemblance to that required in the methods of Legendre. [PARALLELS.]

SIMILE is defined by Johnson to be "a comparison by which anything is illustrated or aggrandised," a definition which has been often neglected by poets. A metaphor differs from a simile in expression, inasmuch as a metaphor is a comparison without the words indicating the resemblance, and a simile is a comparison where the objects compared are kept as distinct in expression as in thought. The metaphor is only a bolder and more elliptical simile. When we speak of the rudeness of a man, and say, "Mr. Jones is as rude as a bear," we use a simile, for the rudeness of the two are kept distinct but likened; when we say "that *bear* Mr. Jones," we use a metaphor, the points of resemblance being confounded in the identification of rudeness with a bear. So, "brave as a lion" is a simile—the "lion Achilles" a metaphor. Where the resemblance is obvious, it may be more forcibly and as intelligibly expressed by a simple metaphor; but when the resemblance is not so obvious, it requires fuller elucidation, and then it must be expressed by a simile. Similes therefore, from their tendency to detail, are usually misplaced in passionate poetry, but metaphors constitute the very language of passion; for the mind, when moved, catches at every slight association to express itself, but never dwells on them with the deliberateness of a comparison.

SIMILOR. A kind of gold-coloured brass. [BRASS.]

SIMONY. [BENEFICE.]

SIMOOM. [SAMIELL.]

SIMPLE BODIES. [ATOMIC THEORY.]

SIMPLE CONTRACT debts are those which are contracted without any engagement under the seal of the debtor or of his ancestor [DEED], and which are not of record by any judgment of a court. Money due for goods bought by the debtor is the most usual of simple contract debts; and the declaration against a defendant, in an action for goods sold, usually alleges that the defendant undertook (or contracted) to pay the plaintiff the sum due. Simple contract debts are the last which are payable out of a deceased person's estate, when the assets are insufficient.

SIN. One of the few passages of Scripture in which we have something which approaches to the character of a definition relates to this word: "Sin is the transgression of the law." (1 John iii. 4.) Within this definition would be comprehended all actual sins, when the word law is interpreted to mean the Christian law, the rule by which the minds of all who profess Christianity are bound; not merely open palpable offences against the law, such as murder, theft, lying, and the like, but sinful omissions of duty, and those sins which are only those of contemplation and thought: since the Christian rule commands us not to neglect the performance of our duties, and to keep a watch over the thoughts as well as over the actions and words.

It was this comprehensive and most excellent law which was in the mind of the Apostle when he said that "sin was transgression of the law," or at least that other divine law which bound the conscience of the Jews. But the expression may be taken to express more generally any law which a person holds in his conscience to be binding upon him, whether it be a law of nature only, or a law in which the natural perception of right and wrong is modified by and mixed with what is received as the will of God concerning us by direct revelation from him.

When the word sin is applied to any act, it is always, among correct writers or speakers, used with reference to religious obligation, and to the responsibility in which we stand to God, and the liability in which we are to future punishment. "To do wrong" would express the same act as "to commit sin;" but we use the former phrase without thinking of the offence which is done against God in any act of the kind; not so when we use the other phrase.

Under this definition it is evident that there may be degrees in sin: and we mention this to remove what we deem an erroneous opinion on this subject, which goes the length of saying that there is really no difference between the slightest violation of any moral obligation and the more heinous transgressions. The error on this point arises out of one of the commonest mistakes in respect of language—confounding words in their abstract with words in their concrete state. It is true that sin in the abstract is one and indivisible, and there are no degrees in it; it expresses that which is most offensive in the sight of a pure, holy, and judging God. But when we say "a sin," we refer to some particular act; and common sense tells us that in all acts in which the law is trangressed there is not the same amount of moral turpitude, not the same amount of defiance to the Divine Power, nor the same injury to society or to our neighbour, and consequently not the same amount of offence in the sight of God. But a watchful guard should be kept; for nothing is more certain in the philosophy of mind, than that small offences lead imperceptibly to the toleration of greater, so that the man who thinks little of small offences may become, before he is aware, guilty of those of the most heinous nature.

There is also what divines call Original Sin; a phrase which is differently interpreted by different persons. By some it is considered as being the act of sin committed by our first parents when they transgressed the law which had bound them not to eat of the fruit of a certain tree; and this act of sin is regarded as partaken in by all the posterity of Adam, fixing upon them all the guilt of his sin, and exposing them to punishment which would be inflicted for this particular sin, to say nothing of their own sin, but for the great redemption. There are many modifications of this notion and many shades of opinion; and some classes of professing Christians do not use the phrase original sin, though they admit the proneness of man to sin; attributing it to his ignorance and imperfection, to the violence of his appetites and passions, and in general referring it to that state of probation in which it seems to them to have been the intention of the Creator to place us.

SINAMINE. [THEISINAMINE.]

SINAPIC ACID ($2HO, C_{22}H_{10}O_8$).—A product of the action of caustic potash on SINAPINE. The *sinapate of potash* ($2KO, C_{22}H_{10}O_8$) thus produced is decomposed by hydrochloric acid, and the precipitated sinapic acid crystallised from hot diluted alcohol. Sinapic acid forms small prisms which are insoluble in ether and only slightly soluble in water. Both itself and its salts are somewhat unstable. It fuses above 300° Fahr.

SINAPINE. ($C_{32}H_{23}NO_{10}$). The hydrosulpho-cyanate of sinapine occurs in white mustard. After the mustard flour has been successively treated with ether and with absolute alcohol to remove fatty and colouring matter, it is boiled in alcohol of sp. gr. 0·825, and the filtered liquid concentrated till, on cooling, it deposits crystals. Sinapine reduces the salts of copper, silver and gold. Its solutions are very liable to decompose into SINAPIC ACID and SINKALINE; a change that is rapidly effected by ebullition with solution of potash:—

$$\underbrace{C_{32}H_{23}NO_{10}}_{\text{Sinapine.}} + 2(KO,HO) = \underbrace{2KO, C_{22}H_{10}O_8}_{\text{Sinapate of potash.}} + \underbrace{C_{10}H_{13}NO_2}_{\text{Sinkaline.}} + 2HO$$

Sinapine was formerly called *sulphosinapisine*.

SINA'PIS. Two species of this genus are used in this country to yield the mustard of commerce, *S. alba* and *S. nigra*, or white mustard and black mustard. Both are annuals, the latter extensively cultivated in Yorkshire and Durham. Of the former the seeds are large, smooth, not veined or reticulated, and when bruised and mixed with water, do not evolve a pungent odour. The integument or skin is also thin, and the quantity of fixed oil obtained from it is less than from that of the black mustard. White mustard is of a light colour externally (but one variety is blackish), and when reduced to powder, is of a light yellow colour.

The seeds of black mustard are about the size of the head of a common pin, ovate-globose, of a reddish-brown, beautifully veined, internally yellow, oily, and yielding a yellowish-green powder. The chemical constitution of the two is essentially different, as it is only the black mustard which evolves, when bruised and mixed with water, the pungent principle which irritates the eyes, nostrils, and skin. The white mustard possesses a non-volatile acrid principle, which is developed by the addition of water; also a peculiar principle, sulpho-sinapisin. It is the young plants from this species which are eaten with cress as a salad.

The fixed oil is perfectly bland, like that of olive or rape, which last it greatly resembles. It exists to the extent of 20 per cent in white, and about 28 per cent. in black mustard-seed. To obtain it the seeds are crushed in a mill or between rollers, and the skins should be subjected to pressure as well as the farina or flour. The cake may then be sifted and reduced to a fine powder, as it retains all the pungent properties. In France the oil is generally left in the seeds, which renders them very difficult to powder, and makes it expensive. It is also less potent than English mustard in equivalent quantity. The marc or cake is sometimes used as manure, but this is a waste. It has been supposed to be anthelmintic as well as purgative, but its medicinal properties are insignificant.

Pure flour of mustard ought alone to be used for medical purposes, but it is seldom to be met with; the mustard of the shops is a mixture of the flour of both black and white mustard with wheat flour and capsicum.

Flour of mustard, mixed with water, forms the well-known condiment so much used with all the more indigestible articles of food, the solution of which it seems to favour by rousing the powers of the stomach. A tea or table-spoonful of mustard in a tumbler of water forms a ready and useful emetic in many cases of poisoning, especially when narcotic poisons have been taken; also in cholera. Added to foot-baths, mustard has a revulsive action, which is often serviceable in the commencement of colds, and when gout has seized the stomach or brain; also when cutaneous diseases have suddenly receded. (RUBEFACIENTS.)

Sinapisms are generally directed to be made with vinegar, but water of the temperature of about 100° Fahr. is preferable, and less expensive. French mustard for the table is often prepared with vinegar.

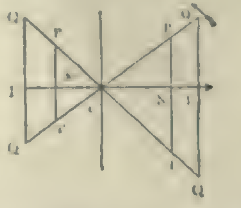
S. nigra differs from the white mustard in the flowers being much smaller, and in the seeds being black. The great purpose for which the black mustard is grown is for the seeds. "To raise the seed for flour of mustard and other officinal occasions, sow either in March or April in an open compartment, or large sowings in fields, where designed for public supply. Sow moderately thick, either in drills six or twelve inches asunder, or broad-cast, after the ground has been properly ploughed and harrowed, and rake or harrow in the seed. When the plants are two or three inches high, hoe or thin them moderately where too thick, and clear them from weeds. They will soon run up to stalks, and in July, August, or September return a crop of seed ripe for gathering; being tied up in sheaves and left three or four days on the stubble." (Don's Miller.) Rain damages the crop very much. Black mustard exhausts the soil rapidly. When once grown it is difficult to extirpate on account of the great vitality of the seeds, which, if buried at almost any depth and for any length of time, will germinate when brought to the surface. In preparing the flour of mustard in this country, the black husk of the seed is separated by delicate sifting. This process, which is not gone through on the Continent, makes the British mustard so much lighter and more agreeable in colour.

SINAPOLINE. [MUSTARD, OIL OF.]

SINDOC, or SINTOC (a word not to be confounded with Sindhooka, or Sinduya, the Indian name of the *Vitex Negundo*), is the bark of a species of cinnamomum (*C. sintoc*, Blume), a native of the forests of Java. It greatly resembles the bark of *Cinnamomum culilawan*, Blume, and partakes of the qualities of Ceylon cinnamon in a very inferior degree. The bark is in thick flat pieces, not in thin quill-like pipes. Its oil is like that of cassia. The bark is used as a spice; the oil as a medicine and perfume by the natives. It is seldom brought to Europe in any shape.

SINE and COSINE. We separate from the article TRIGONOMETRY the mere description and properties of these fundamental terms, which, though originally derived from simple trigonometry, are now among the most useful foundations of mathematical expression. For what we have to say on their history, we refer to the article just cited.

According to the ancient system of trigonometry, the sine and cosine are only names given to the abscissa and ordinate of a point, not with reference to the position of that point in space, but to the radius vector of that point and its angle. Thus, measuring angles from the line ON, and in the direction of the arrow, the angle NOP has an infinite number of sines and cosines. With reference to the *radius* OP, PN is the sine and ON the cosine of ∠ NOP; but with reference to the radius OQ, QR is the sine and OR the cosine. The fundamental relation



$$(\text{sine } \theta)^2 + (\text{cosine } \theta)^2 = (\text{radius})^2$$

is obvious enough.

The student always began trigonometry with this multiplicity of definitions, and with the idea of some particular radius being necessary to the complete definition of the sine and cosine. But as he proceeded, he was always taught to suppose the radius a unit; that is, always to adopt that line as a radius which was agreed upon to be represented by 1. Hence he gradually learned to forget his first definition; and, passing from geometry to arithmetic, to use the following: PO being unity, the sine of NOP is PN, which is therefore in arithmetic the fraction which PN is of PO; and the cosine is the fraction which ON is of PO. If QO had been used as a unit, the result would have been the same; for by similar triangles, RQ is the same fraction of QO which NP is of PO.

In the most modern trigonometry, and for cogent reasons, the student is never for a moment allowed to imagine that the sine and cosine are in any manner representatives of lines. In a practical point of view, the final definition of the old trigonometry coincides exactly with that of the new; but the latter has this advantage, that all subsequent geometrical formulæ are seen to be homogeneous in a much more distinct manner. The definition is this: The sine of NOP is not NP, nor any number to represent NP; it is the fraction which NP is of PO, considered as an abstract number. Thus if ON, NP, PO, be in the proportion of 3, 4, and 5, PN is $\frac{4}{5}$ of OP: this $\frac{4}{5}$ is the sine of NOP, not $\frac{4}{5}$ of any line, nor any line considered as $\frac{4}{5}$ of a unit; but simply $\frac{4}{5}$, four-fifths of an abstract unit. Similarly the cosine is the fraction which ON is of OP. In just the same manner the abstract number π, or 3·14159 . . ., is not styled (as it used to be) the circumference of a circle whose diameter is a unit, but the proportion of the circumference to the diameter, the number of times which *any* circumference contains its diameter. We cannot too strongly recommend the universal adoption of this change of style, a slight matter with reference to mere calculation of results, but one of considerable importance to a correct understanding of the meaning of formulæ.

The line OP being considered as positive [SIGN], the signs of PN and NO determine those of the sine and cosine; and the manner in which the values of these functions are determined when the angle is nothing, or one, two, or three right angles, is easy enough. The following short table embraces all the results of sign :—

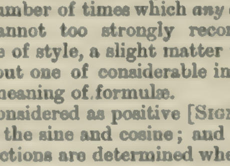
	0		I		II		III		IV
Sine	0	+	1	+	0	−	1	−	0
Cosine	1	+	0	−	1	−	0	+	1.

Read this as follows :—When the angle $=0$, the sine $=0$; from thence to a right angle the sine is positive: at the right angle the sine is $+1$; from thence to two right angles the sine is positive, &c.

The fundamental theorems of the sine and cosine, from which all their properties may be derived, are,

$$\sin(a+b) = \sin a \cos b + \cos a \sin b$$
$$\sin(a-b) = \sin a \cos b - \cos a \sin b$$
$$\cos(a+b) = \cos a \cos b - \sin a \sin b$$
$$\cos(a-b) = \cos a \cos b + \sin a \sin b$$

all which theorems are in fact contained in any one of them, so soon as that one is shown to be universally true. It frequently happens however that the student is allowed to assume the universal truth of these theorems upon too slight a foundation of previous proof: drawing a figure for instance in which both angles are less than a right



angle. We give, as an instance, the proof of the first formula when both angles are greater than two right angles. Let X O P $=a$, P O Q $=b$, both angles being measured in the direction of revolution indicated by the arrow. The sum is four right angles + X O Q, which has the same sine and cosine as X O Q. From any point Q in O Q draw perpendiculars on O X and O P, and complete the figure as shown. Then sin $(a+b)$ is positive, and is the fraction which Q M is of Q O, or Q M : Q O; Q M and Q O being expressed in numbers. But

$$\frac{QM}{QO} = \frac{QS}{QO} + \frac{NR}{QO} = \frac{QS}{QN}\frac{QN}{QO} + \frac{NR}{NO}\frac{NO}{QO}$$

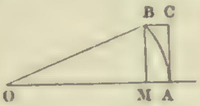
$$\text{By similar triangles} = \frac{OT}{PO}\frac{QN}{QO} + \frac{PT}{PO}\frac{NO}{QO}.$$

Now, remembering the magnitudes of a and b, and the rule of signs established, we have

$$\sin a = -\frac{PT}{PO},\ \cos a = -\frac{OT}{PO},\ \sin b = -\frac{QN}{QO},\ \cos b = -\frac{NO}{QO};$$

and substitution immediately gives the first formula. We shall not here dwell on the minor consequences of these formulæ, but shall refer to the collection in TRIGONOMETRY.

The connection of the sine and angle depends in great part upon the following theorem:—if x may be made as small as we please, $\sin x : x$ may be made as near to unity as we please. Observe that this theorem supposes the angle x to be measured by the theoretical unit [ANGLE], or the angle 1 to be the angle of which the arc and radius are equal. The proof depends upon the assumption that in the adjoining obvious figure the arc A B is less than its containing contour A C + C B.



If the radius O B be r, we see that x must be arc A B : r, or A B $=rx$. Also B M $=r \sin x$, B C $=$ A M $=r-r\cos x$, by definition. Now the arc A B is greater than B M, and less than B M + M A, or rx lies between $r \sin x$ and $r\sin x+r-r\cos x$, or x lies between $\sin x$ and $\sin x+1-\cos x$;

$$\text{or between } \sin x \text{ and } \sin x + \frac{\sin^2 x}{1+\cos x};$$

$$\text{whence } \frac{x}{\sin x} \text{ lies between 1 and } 1 + \frac{\sin x}{1+\cos x}.$$

Hence, x diminishing without limit, the difference between 1 and $x : \sin x$ diminishes without limit, and therefore that between 1 and $\sin x : x$ which was to be proved. From hence it follows that $1-\cos x$ and $\frac{1}{2}x^2$ approach to a ratio of equality, as may be readily proved from the equation

$$1-\cos x = \frac{x^2}{2}\cdot\left(\frac{\sin x}{x}\right)^2\cdot\frac{2}{1+\cos x}$$

in which the second and third factors have unity for their limit. Hence then, when x is very small, x and $1-\frac{1}{2}x^2$ are very near representatives of the sine and cosine; and the goodness of the representation may be increased to any extent by diminishing x.

The complete theory of the sine and cosine, from and after the two theorems just established, depends upon the introduction of the square root of the negative quantity. If we take ordinary algebra only, in which the impossible quantity is unexplained, we have the most common mode of proceeding. The explanations afterwards given would make this theory the most simple imaginable, to a student who had learned ALGEBRA from the beginning in the manner pointed out. To take the middle course, let us assume the rules of algebra [OPERATION] independently of the meanings of the symbols. Let $\sin x$ and $\cos x$ be defined as "such functions of x that $\sin(x+y)$ gives $\sin x.\cos y+\cos x.\sin y$, and $\cos(x+y)=\cos x.\cos y-\sin x.\sin y$." Observe that we do not in thus defining say there *are* such functions; we only say, *if there be* such, let them have these names. Then, as in ALGEBRA cited above, we see that if $\phi x=\cos x+\sqrt{-1}.\sin x$, the relation $\phi(x+y)=\phi x\times\phi y$ follows; whence [BINOMIAL THEOREM] ϕx can be nothing but K^x, where K is independent of x. Let $x=1$, whence $\phi(1)=K$, or we have

$$\cos x+\sqrt{-1}.\sin x=(\cos 1+\sqrt{-1}.\sin 1)^x \ldots (1)$$

and similarly it is shown that

$$\cos x-\sqrt{-1}.\sin x=(\cos 1-\sqrt{-1}.\sin 1)^x \ldots (2).$$

From these we get, by multiplication,

$$\cos^2 x+\sin^2 x=(\cos^2 1+\sin^2 1)^x: \ (3)$$

if it be possible, let $\cos^2 1+\sin^2 1=1$, then $\cos^2 x+\sin^2 x$ is always $=1$, or at least [ROOT] we may always take one pair of forms satisfying this condition. Hence, making $\cos 1+\sqrt{-1}.\sin 1=e$, we have $\cos 1-\sqrt{-1}.\sin 1=e^{-1}$, and the two equations give

$$\cos x = \frac{e^x+e^{-x}}{2} \quad \sin x = \frac{e^x-e^{-x}}{2\sqrt{-1}} \quad (4)$$

which will be found to satisfy all the conditions used in defining them, namely,

$$\frac{e^{x+}+e^{-x-y}}{2} = \frac{e^x+e^{-x}}{2}\ \frac{e^y+e^{-y}}{2} - \frac{e^x-e^{-x}}{2\sqrt{-1}}\ \frac{e^y-e^{-y}}{2\sqrt{-1}}$$

$$\frac{e^{x+y}-e^{-x-y}}{2\sqrt{-1}} = \frac{e^x-e^{-x}}{2\sqrt{-1}}\ \frac{e^y+e^{-y}}{2} + \frac{e^x+e^{-x}}{2}\ \frac{e^y-e^{-y}}{2\sqrt{-1}}$$

$$\left(\frac{e^x+e^{-x}}{2}\right)^2 + \left(\frac{e^x-e^{-x}}{2\sqrt{-1}}\right)^2 = 1$$

To determine what algebraical formula e must be, take the universal formula

$$e^x = 1+\log e.x+(\log e)^2\frac{x^2}{2}+(\log e)^3\frac{x^3}{2.3}+\ldots$$

whence we easily get from (4)

$$\sin x = \frac{\log e}{\sqrt{-1}}.x+\frac{(\log e)^3}{\sqrt{-1}}\frac{x^3}{2.3}+\frac{(\log e)^5}{\sqrt{-1}}\frac{x^5}{2.3.4.5}+\ldots\ldots$$

$$\cos x = 1+(\log e)^2\frac{x^2}{2}+(\log e)^4\frac{x^4}{2.3.4}+\ldots\ldots$$

Now e, as far as our definitions have yet extended, is wholly undetermined, every value of e being applicable. Let us add to our conditions that $\sin x : x$ shall approach to unity as x is diminished without limit: but $\sin x : x$ approaches to $\log e : \sqrt{-1}$; therefore $\log e=\sqrt{-1}$, or $e=\epsilon^{\sqrt{-1}}$.

The preceding is purely symbolical; we merely ask how are previous symbols, used under certain laws, to be put together so as to represent certain new symbols which are to have certain properties. Let us now take the real geometrical meaning of $\sin x$ and $\cos x$, and the complete system of algebra, in which $\sqrt{-1}$ is explained. In that system, if a line equal to the unit-line be inclined to it at an angle x, it is obviously represented by $\cos x+\sqrt{-1}.\sin x$, and any power of it, whole or fractional, can be obtained by changing x into mx, so that

$$\cos mx+\sqrt{-1}.\sin mx=(\cos x+\sqrt{-1}.\sin x)^m$$

is an immediate consequence of definition; and making $x=1$, the equation

$$\cos m+\sqrt{-1}.\sin m=(\cos 1+\sqrt{-1}.\sin 1)^m$$

follows at once. To prove that $\epsilon^{\sqrt{-1}}$ and $\cos 1+\sqrt{-1}\sin 1$ are identical, in the most logical manner, requires a previous definition of an exponential quantity, in a sense so general, that exponents of the form $a+b\sqrt{-1}$ shall be included: without this the new algebra just referred to is not free from the results of INTERPRETATION.

However we may proceed, the series above given for the sine and cosine of x become

$$\sin x=x-\frac{x^3}{2.3}+\frac{x^5}{2.3.4.5}-\frac{x^7}{2.3.4.5.6.7}+\ldots$$

$$\cos x=1-\frac{x^2}{2}+\frac{x^4}{2.3.4}-\frac{x^6}{2.3.4.5.6}+\ldots$$

and these series are always convergent. Their present form depends entirely on the unit chosen; if however by x we mean x°, x', or x'', we must write

$$\sin x=ax-\frac{a^3x^3}{2.3}+\frac{a^5x^5}{2.3.4.5}-\ldots$$

$$\cos x=1-\frac{a^2x^2}{2}+\frac{a^4x^4}{2.3.4}-\ldots$$

where [ANGLE] a is ·01745,32925 ...., ·00029,08882, ..., ·00000,48481, ... according as x means a number of degrees, of minutes, or of seconds.

The preceding is enough on the fundamental meanings of these terms, and on their connection with algebra. Some applications will be seen in TRIGONOMETRY.

SINE and COSINE, CURVES OF. By the curve of sines is meant that which has the equation $y=\sin x$, and by the curve of cosines, that which has the equation $y=\cos x$; it being understood that x stands for as many angular units as there are linear units in the abscissa. The undulatory forms of these curves are easily established; and if the ordinate of a curve consist of several of them, as in $y=a\sin x+b\cos x+c\sin 2x$, the several parts of the compound ordinate may be put together in the same manner as that in which the simple undulations are compounded in ACOUSTICS. Except as expressing the most simple form of undulating curves, these equations are of no particular use in geometry.

SINE-CURE. Sine-cures are ecclesiastical benefices without cure of souls, and are of three sorts:—1. Where the benefice is a donative

[Benefice], and is committed to the incumbent by the patron expressly without cure of souls, the cure either not existing or being entrusted to a vicar; this is the strictest sine-cure. 2. Certain cathedral offices, namely, the canonries and prebends, and, according to some authorities, the deanery. 3. Where a parish is destitute, by some accident, of parishioners; this last kind has been called depopulations, rather than sine-cures.

Rectors of a parish in which vicars were likewise established with cure of souls have often by degrees exempted themselves from their ecclesiastical functions, and so have obtained sine-cures; but this is rather by abuse than legitimately. Sine-cures are exempt from the statute of pluralities.

SINETHYLAMINE. [Theisinamine.]

SINKALINE. ($C_{10}H_{13}NO_2$)—This alkaloid is a derivative of Sinapine. It is best obtained by heating hydro-sulphocyanate of sinapine with baryta water until precipitation of sinapate of baryta ceases; then taking out hydrosulphocyanic acid by the sulphate of copper and iron; again adding excess of baryta water, and lastly separating baryta by a current of carbonic acid. From the solution of carbonate of sinkaline, thus obtained, the other salts may be formed by double decomposition. The alkaloid itself is produced by the action of oxide of silver on hydrochlorate of sinkaline.

Solution of sinkaline is very unstable. Evaporated in vacuo, a crystalline mass of the alkaloid is obtained, soon becoming brown in contact with air. *Chloroplatinate of sinkaline* contains ($C_{10}H_{13}NO_2$, HCl, $PtCl_2$).

SINKING FUND. [National Debt, col. 878.]

SIOUX INDIANS. [North American Indians.]

SIPHON (*σίφων*), a tube or pipe by which a liquid can be decanted from one vessel to another without inverting or disturbing the vessel from which the liquid is withdrawn. This machine was probably invented in the second century B.C., by Hero of Alexandria, who, in the 'Spiritalia,' or 'Pneumatics,' mentions its employment for the purpose of conveying water from one valley to another over the intervening ground.

The siphon is a bent tube the arms of which are of unequal length: one of the arms being immersed in the liquid which is to be drawn from a vessel or reservoir, and the air being removed by suction, or by means of a syringe, or by previously filling the siphon, the liquid in the vessel immediately rises in the immersed arm, in consequence of the pressure of the atmosphere on that which surrounds the tube; then passing over the bend, it flows from the open orifice at the lower extremity of the other arm. When the fluid to be raised is water, the vertical height of the bend in the tube, above the surface of the water in the vessel, must not exceed about 33 feet, because a column of water of that height would be in equilibrium with the pressure of the atmosphere, and could not by the latter be forced over the bend. If mercury were to be raised, the height of the bend in the siphon must, for a similar reason, be less than 30 inches. The external arm of the siphon must be longer than that which is immersed in the fluid, or its orifice must be on a lower level than the surface of that fluid, in order that the weight of the column of fluid in the former may exceed that in the latter, and thus a continual stream be produced.

The siphon is sometimes furnished with a suction or exhausting pipe at the side, by means of which the air can be conveniently removed and the liquid be made to rise over the bend into the longer limb. In the *Wurtemberg siphon* the two ends are turned up, so that when once filled it will always remain so, and act at once when one end is immersed into a liquid.

A siphon may be made to discharge water at the upper extremity by means of an air-vessel at that place. Thus, while the tube is filled with water, if the communication between the descending branch and the lower part of the air-vessel be closed by the shutting of a valve, the water, which would have otherwise descended, rises in the vessel, where it condenses the air; and, from the reaction of the latter, it is made to escape, as in a forcing-pump, through an open pipe whose lower extremity is under the surface of the water in the vessel. This was the invention of M. Hachette, and is denominated the *ram siphon*.

In order that a fluid may issue from that branch of a siphon which is on the exterior surface of the vessel containing it, it is necessary, as has been stated above, that the extremity of the branch should be below the level of the surface of the fluid in the vessel; but it may be observed that there is an exception to the rule when the interior diameter of that branch is very small; for example, when it is less than 1-10th of an inch, the interior diameter of the branch in the vessel being considerably greater. For if such a fluid as water or wine be introduced into a bent tube having one branch only very small, and the open ends be uppermost, the top of the fluid in the more slender branch will, by the effect of capillary attraction, stand higher than the top of that in the other branch. It would follow therefore, that if the bent tube were inverted, and the orifice of its larger branch were placed under the surface of the fluid in a vessel, the fluid would begin to issue from the other branch, though the orifice of the latter were a little above the level of that surface.

The effect of a siphon may be produced by capillary attraction alone; for if a piece of cotton cloth have one of its extremities in a vessel of water, and part of it be made to hang over the edge of the vessel, the water will be attracted along the threads of the cloth, and will descend from thence in drops, provided the extremity of the part thus hanging over be below the surface of the water in the vessel.

The phenomena presented by springs of water are explained by supposing that the rain which is absorbed in the earth occasionally finds its way by small channels to some interior cavity, and from thence by other channels, which may be considered as natural siphons, to an orifice on a lower level at the surface of the ground. At this orifice it issues in a stream of water, which continues to flow till the surface of the water in the cavity has descended below the tops of the vertical bends in the channels: the water then ceases to flow till the rains again raise the water in the cavity above those bends. But it sometimes happens that a spring, without ceasing to flow, discharges periodically greater and smaller quantities of water in given times; and this is accounted for by supposing the existence of two cavities either unconnected or communicating with one another by small channels. The channels leading from one of these cavities to the point of efflux are supposed to be below the level of the water in both cavities, so that the water flows through them continually; but if the channels from the other have vertical bends, so that they act as siphons, and at the same time these channels carry off the water in them faster than it can flow from the first cavity to the second, it will be only when the water in the latter cavity is above the level of all such bends that a discharge will take place from thence. As the water in that cavity may only attain the necessary height in consequence of periodical falls of rain, it will follow that corresponding increases in the total quantity of water discharged can only then take place.

For the amusement of young persons, several philosophical toys have been constructed, in which the effects are produced by means of concealed siphons. The siphon is sometimes placed within a figure in the middle or on the edge of a cup, and sometimes between its exterior and interior sides. Such are *Tantalus's Cup* and the *Siphon Fountain*.

SIPHON GAUGE, in pneumatics, is a tube of glass bent so as to form two branches equal and parallel to one another, and each from 6 to 8 inches in length; the tube is hermetically closed at one end and left open at the other. One of the branches is filled with mercury; and, both of them being in vertical positions, with the closed and open ends upwards, they are, by means of a brass stem terminating in a screw, affixed generally to the under surface of the table carrying the plate of an air-pump. The siphon is contained in a cylindrical glass vessel, a little exceeding it in length, which is closed at the lower and open at the upper extremity; and the open end of the cylinder is screwed to the table of the air-pump immediately about the orifice of a brass tube which passes through the pump-plate and opens into the receiver placed upon the plate, so that there is a free communication between the air in the cylinder, in the open leg of the siphon, and in the receiver. This gauge has a scale of inches, decimally subdivided. While the pressure of the air in the receiver and in the open branch of the gauge is more than a counterbalance to the weight of the column of mercury in the closed branch, the gauge presents no indications: from the time however that, by continuing the process of exhausting the receiver, the pressure of the air in the open branch becomes less than the weight of the column of mercury in the other, that column descends in the latter branch and rises in the former; and then the degree of rarefaction in the receiver is indicated by the difference between the heights of the columns of mercury in the two branches of the siphon. [Air-Pump; Pear-Gauge.]

SIRENS (*Σειρῆνες*) are described in the 'Odyssey' as two maidens who sat by the sea and so charmed with their music all who sailed by, that they remained on the spot till they died. Ulysses, by the direction of Circe, had himself tied to the mast, and stopped the ears of his companions with wax, by which means he was able to hear their music, and escape from its influence. ('Od.' xii. 39, &c., 169.) The ship of Ulysses, with himself tied to the mast, is frequently represented on gems, and other works of ancient art. The number of the Sirens was afterwards increased to three, who are variously named by different writers, Parthenope, Ligeia, and Leucosia; or Aglaope, Peisinoë, and Thelxiepia. They were usually called the daughters of Melpomene and Achelous (Apollod., i. 3, § 4), and were represented by artists with the feathers and wings of birds. (Compare Ovid, 'Met.,' v. 522, &c.) According to the later writers they were urged by Hera to contend with the Muses, who conquered them, and tore off their wings. (Paus., ix. 34, § 2.)

SIRIUS and PROCYON (*Σείριος* and *Προκύων*), the Greek names of the bright stars in the constellations of the Great and Little Dog [Canis Major and Minor]. These are Orion's dogs, according to some, and those of minor personages, according to others; the whole of their mythic explanations form a strong proof, in addition to those already noticed, that the constellations are not Greek in their origin. The Egyptians called the dog-star Sothis [Sothiac Period], and from its heliacal rising had warning that the overflow of the Nile was about to commence. Now the overflow of the Nile follows the summer solstice; whereas, by the precession of the equinoxes, the heliacal rising of Sirius is now about the tenth of August. This heliacal rising is a very indefinite phenomenon, and will serve any system: by it Bailly, from Bainbridge's calculations, was able to carry back the settlement of Egypt 2800 years before Christ: while Newton, by a reckoning made on the same principles, made many ancient events seem later than was generally supposed.

The greatest heats of summer generally follow the summer solstice, and in the Mediterranean latitudes, and in ancient times, it was observed that the unhealthy and oppressive period coincided with the heliacal rising of the dog-star. We say *the* dog-star, without specifying whether it was Sirius or Procyon; it is uncertain which it was, and may have been both, for the heliacal risings do not differ by many days. All antiquity attributed an evil influence to the star; and though Geminus among the ancients, and Petavius among the moderns, thought that the effects were to be attributed to the sun alone, they had hardly any followers until the fall of judicial astrology. Even at this day, when the heats of the latter part of the summer are excessive, we are gravely told that we are in the dog-days; and most of the almanacs, in which an absurdity has the lives of a cat, persist to this very year in informing us that the dog-days begin on the 3rd of July, and end on the 11th of August. Now as the heliacal rising of Sirius takes place about the very end of this period, it is clear that the cart has got before the horse, or the mischief before the dog. Moreover, it is notorious that in our island the oppressive heats of the summer, during which dogs are apt to run mad (which is what many people think the name arises from, as indeed it was anciently recorded among the effects of the star), generally fall about the middle or end of August. The real classical dog-days are the twenty days preceding and the twenty days following the heliacal rising of whichever star it was, Sirius or Procyon. It is perfectly useless to retain this period: surely these dogs have had their day.

SIROCCO is the name given to a hot and suffocating wind which appears to originate with the rarefied air in the sandy deserts of Arabia, about the season that the overflowing of the Nile commences; it extends eastward over Arabia, Persia, and some parts of Hindustan, and it is felt, but with less inconvenience, in Italy and Spain. This wind is probably only one of the modifications of that which, in different countries, is called *samoom*, *simoom*, *samm* or *samieli*, *khamsin*, and *harmattan*. [SAMIELI.]

SISSOO (*Dalbergia Sissoo*), a tree well known throughout the Bengal presidency, and highly valued on account of its timber. It is common chiefly in the forests and beds of rivers which extend all along the foot of the Himalayas up to 30° N. lat. The trunk is generally more or less crooked, lofty, and often from three to four feet in diameter. The Sissoo yields the Bengal shipbuilders their crooked timbers and knees. Dr. Roxburgh describes it as being tolerably light, remarkably strong, but not so durable as could be wished; the colour is light grayish-brown, with dark veins: he says that upon the whole he scarcely knows any other tree more deserving of attention, from its rapid growth in almost every soil, its beauty, and uses. Captain Baker, in his 'Experiments on the Elasticity and Strength of Indian Timbers,' describes the Sissoo in structure somewhat resembling the finer species of teak, but as being tougher and more elastic, and as employed by the natives for house furniture, beams, cheeks, spokes, naves and felloes of wheels, keels and frames of boats, blocks, and printing-presses. It is universally employed both by Europeans and natives of the north-west provinces where strength is required. *S. Dalbergia Ougeinensis*, found in central India, is also highly valued for timber: the pillars of Sindia's palace at Ougein are made of it.

SISTRUM, a musical instrument of percussion, of great antiquity, constructed of brass, and shaped like the frame and handle of a racket, the head part of which had three, and sometimes four, horizontal bars placed loosely on it, which were tuned, most probably, by some scale, and allowed to play freely, so that when the instrument was shaken, piercing, ringing sounds must have been produced. Some writers have confounded the sistrum with the cymbals, though the instruments could have had nothing in common except their harsh metallic sounds.

SIVA, the personification of the destroying principle, forms, with the two other gods, Brahma and Vishnu, the Trimûrti, or triad, of the Hindus; and although, in allusion to his office as destroyer, he is classed third, yet he is generally allowed to occupy the second place among the Hindu deities, or even (according to some) the first, as his supremacy appears to have obtained more general assent than that of Vishnu. Indeed the worship of Siva is so predominant, that Brahma, who is the only one of the three mentioned by Manu, and who seems to have enjoyed a larger share of adoration in ancient times, has now only one temple in India, while Mahâdeva (a name of Siva) and the adventurous Vishnu, whose incarnations attract so much of the veneration of the Hindus, are, in fact, the only gods of the whole Hindu pantheon who have numerous worshippers. The present popular form of Siva worship in all probability assumed its actual state before the great Saiva reformer, Sankara Acharya, who lived in the eighth or ninth century. ('Vishnu Purâna,' pref., p. x.) This opinion is supported by the well-founded assertion that the Saiva faith was instituted by Paramata Kalânala, who is described in the 'Sankara Vijaya' of Ananda Giri as teaching at Benares, and assuming the insignia that characterise the Dandis, a sect of Saivas of modern times. ('As. Res.,' xvi. 22.) No allusion is made in the Purânas to the original power of this god as destroyer; that power not being called into exercise till after the expiration of twelve millions of years, when, according to Puranic accounts, the Kaliyuga will come to a close together with the universe; and Mahâdeva is rather the representative of regeneration than of destruction. The linga is the only form under which Siva is now adored in most parts of India. According to Professor Wilson ('Vishnu Purâna,' xliv.), "There is nothing like the phallic orgies of antiquity; it is all mystical and spiritual." The linga is twofold, external and internal. The ignorant, who need a visible sign, worship Siva through "a mark" or "type," which is the proper meaning of the word "linga," of wood or stone; but the wise look upon this outward emblem as nothing, and contemplate in their minds the invisible inscrutable type, which is Siva himself. But his other forms are many, and they vary in so far as they attribute to him the qualities of creator, preserver, destroyer, and regenerator, and represent him in his various *avatâras* (incarnations), eight of which are called by the common name of Bhairava, all alluding to terrific properties of mind or body. He is sometimes seen with two hands, at others with four, eight, or ten, and with five faces; he has a third eye in his forehead, the corners of which are perpendicular, which is peculiar to him; a crescent in his hair, or on his forehead, encircling the third eye; he wears ear-rings of snakes, and a collar of skulls. Mahâdeva, when represented thus, but with one head, has four hands, in one of which he holds a pâsa, the use of which is to extract the souls out of the bodies of men, when their time is come, and is a common attribute of Yama, the god of death ('S. Sâvitryupakhyana,' ed. Bopp.), a tris'ula is upheld by the other, and the two other hands are in a position of benediction. As Bhairava (the lord of dread) he is frightful to behold; great tusks burst through his thick lips; the hair, which is stiff and erect, gives his face a dreadful aspect; the fall of the necklace is impeded by numerous snakes which twine round his body. This is also the idol which shows him as Mahâ-kâla, or god of time. It is in this character that he is supposed to delight in bloody sacrifices, and that the Saiva Sannyâsis (followers of Siva who practice the yoga to the highest degree) inflict on themselves the cruelties which have rendered so conspicuous the temple of Jaggernaut (Jagannâtha, the lord of the world). [YOGA.] A very minute account of the fortitude and self-denial of the deluded Yogis is given in Ward's 'View of the Religion of the Hindus.' His consort Sakti, who in her corresponding character is celebrated as the goddess Durgâ or Kâlî, participates in these horrible sacrifices, and has of late years become more notorious by the exposure of the homicidal practices of the Thugs, who recognise in her their tutelary divinity. Siva is also the god of justice. In that character he rides a white bull, the symbol of divine justice (Manu, viii. 16), and is often seen with the *parashu* (battle-axe) in his hand, and the sacred string. On pictures he is often represented as if rubbed over with ashes, and with a blue neck; the epithet of Nîlakanta (blue-necked) was given to him in commemoration of his having drunk the poison which arose from the sea, and threatened to destroy mankind. But the character in which he is more generally known, and which his followers imitate, is that of the Kapâla-bhrit (skull-bearer). Skanda-Purâna makes him describe himself in the following words:—"Pârvatî (his bride) must be foolish to practise so severe a penance in order to obtain me, Rudra (one of his 1000 names), a wandering mendicant, a bearer of a human skull, a delighter in cemeteries, one ornamented with bones and serpents, covered with ashes and with no garments but an elephant's skin, riding on a bull, and accompanied by ghosts and goblins." Now this, except that the unearthly beings who follow him are represented by a crowd of dirty people, is exactly the description of a Saiva digambara (sky-clad, that is, naked—a kind of religious mendicants), if, instead of the god's third eye, we add a round dot on the nose, made of clay or cow-dung, and a mark on the forehead, composed of three curved lines, instead of the *chandra* (half moon) which Rudra obtained at the churning of the ocean.

To continue the account of his adventures: Siva marries Pârvatî, and lives with her in the midst of the eternal snows of Mount Kailâsa. His heaven is however one of the most splendid in Hindu mythology, and a description of it may be found in Ward's 'View;' it is a translation from the Kritya Tatwa. There also are his two sons; Ganesa, the leader of the heavenly choristers, and, as Vigneswara, the god of difficulties, whose head is that of an elephant; and Kartikeya, the six-faced god of war. It is there that he was thus addressed by Brahma and the other gods:—"I know that thou, O Lord, art the eternal Brahm, that seed which, being received in the womb of thy Sakti (aptitude to conceive), produced this universe; that thou, united with thy Sakti, dost in sport create the universe from thy own substance, like the web from the spider." Here it was that he reduced to ashes the "flowery-bowed mind-bewitcher" Kâma (the god of love), pierced by whose arrows he had neglected to avenge the wrong done to him and his consort by his father-in-law Daksha. On the top of Kailâsa it is that the worshippers of Siva will be admitted to the sports of the inhabitants, where Mahâdeva invented for the amusement of his bride the heavenly dance, to which his faithful attendant Nandi plays the musical accompaniment. There lie before the door his vehicle, the white bull, and the tiger on which his consort rides. Though wanting all the splendours of the Swarga (Indra's heaven), the abode of Siva, when drawn in the glowing colours of the East, is no less gratifying. From thence he is supposed to bless his worshippers, "when, with Pârvatî on his knees, he, the lord of the world, on whose brow shines the moon throwing its beams over the mountain of the north, deigns to allow the Suras and Asuras (gods and dæmons) to wear for their frontal ornament the reflection of the radiance of the nails of his feet, and the Ganga, rushing from the top of his head, refreshes the air of his sacred dwelling" (*Kathá Sarit Ságara*). This is a favourite subject among the Hindu painters, and we must allow that their conception of it is generally well executed.

The numerous names of Siva have led Europeans into a notion contrary to that which induced the Hindus to make the linga the general type for all the forms of this god; they naturally enough supposed each of his numerous names and pagodas to belong to a distinct and separate deity. Hence the erroneous notion about polytheism in India, whilst it is evident that the original monotheism of Hindu religion had in the progress of time become pantheism, which is prevalent all over the East. Even at present the follower of Siva denies the divinity of Vishnu, and *vice versâ*; although both these gods, now representing the Supreme Being, were only types of divine qualities attributed to the Trimûrti. But the allegory eventually acted too strongly on the imagination of the people. Brahma, as creator, had finished his work, and could not with propriety act any more. Siva therefore and Vishnu were destined to do all that fancy could suggest; but still Mahâdeva is the only god to the Saivas, whilst Narâyana is the one chosen by the Vaishnavas. For this we have the express words of the Radha Tantra, which says that the form of Arddhanareswara (half man, half woman) was assumed by Siva in order to prove that he was the one Brahm, in whom both the female and male powers are united. This notion of the animating and recipient principles being united in one, has been embodied in the statue termed Arddhanarî; one half of Siva, from head to foot, bears all the ornaments of Pârvatî or Bhâvanî; the other is exactly the same as that in which he is usually exhibited.

The rage for identifying the gods of the Eastern nations with those of the West has not spared Siva. He was Bacchus, and Saturn, and Pluto; in fact, he was said to be almost the entire pantheon of Greece and Rome and Egypt. Neither is this to be wondered at, seeing that the Greeks and Latins ascribed different attributes to different deities. The Hindus have only one to whom to ascribe all attributes. Siva is also, and it appears originally, the representative of fire. This element penetrates earth and water, represented by Brahma and Vishnu, imparts to them some of its vigour, develops their qualities, and brings everything in nature to that state of increase, maturity, and perfection which they would not attain without it. But ceasing to act beneficially on the created things, they perish: this agent of reproduction, when free and visible, consumes the body, the composition of which he himself had effected: to this quality he owes his title of god of destruction.

The reader who may wish to see the connection of the Hindu gods with those of Greece and Rome will find ample materials in the papers which Col. Wilford inserted in the earlier volumes of the 'Asiatic Researches:' they cannot however be implicitly relied on.

(Vans Kennedy, *Researches into Ancient and Hindu Mythology*; Maurice, *Indian Antiquities*; Ward, *View of the Religion, Literature, &c. of India*; Wilson, *Vishnu Purâna—Oxford Lectures*; Rolle, *Recherches sur Bacchus et les Mystères*; P. von Bohlen, *Das Alte Indien*; Kindersley, *Specimen of Hindu Literature*; Moore, *Hindu Pantheon*; *Asiatic Researches*; Dubois, *Mœurs, &c. des Peuples de l'Inde.*)

SIVAN (in Hebrew, סִיוָן) is the ninth month of the Jewish civil year. The name is mentioned in the Bible, at Esther viii. 9. In the copies of the calendar of Heliopolis (Balbek) we find Εζηρ, Οζιρ, and Οζιζ; but these words are evidently intended to represent the Syrian month Heziran. No probable Hebrew etymology has been suggested for the word Sivan; but Renfey proposes the Persian month Sefendarmed, which the analogous Zend form shows to be compounded of two words, the first of which, 'spenta,' signifies *pure*. Sivan has thirty days, and it coincides with our May or June; in the year 1860 it began on the 22nd of May and ended on the 20th of June; in 1861 it begins on the 10th of May and ends on the 8th of June. On the 6th of this month Pentecost begins, and some festivals are mentioned as held on the 15th, 16th, and 17th of the month, in commemoration of victories gained by the Maccabees; but they do not appear to be generally observed. The same may be said of certain fasts set down for the 25th and 27th, in remembrance of the death of celebrated rabbis.

SIX CLERKS. The office of Six Clerks was an office of great antiquity connected with the Court of Chancery, probably as ancient as the court itself. The number of the Six Clerks was limited to six as long ago as the 12th Rich. II. The history of this office illustrates the mischief of attempting to regulate the supply of legal services to the client. It exhibits an instance of the principles of interference and monopoly destroying two successive classes of officers, in spite of the strongest support which the law and the courts could give to them.

The Six Clerks were originally the only attorneys of the court. By the common law, any person who was impleaded in any of the courts of law was bound to appear in person, unless he obtained the king's warrant, or a writ from Chancery enabling him to appear by attorney, "by reason whereof," says Lord Coke (1 'Inst.,' 128), "there were but few suits." There are many early statutes still in force enacted for the purpose of empowering the subject to appoint an attorney. The earliest statute is that of Merton (A.D. 1235), whereby it is "provided and granted that every freeman which oweth suit to the county, tithing, hundred, and wapentake, or to the court of his lord, may freely make his attorney to do those suits for him." Subsequent Acts extended this privilege to other parties and other courts; but to this day it would appear that, by the strict law of the land, except so far as it has fallen into desuetude, persons in good health, in pleas relating to money, are bound to appear in person. None of these statutes, however, extended to courts of equity; but, as far as appears, every person who was desirous of relief, or compelled to defend himself in the Court of Chancery, was obliged to employ one of the Six Clerks as his representative.

In early times great exertions were made to limit the number of attorneys who were allowed to practise in each court. The increase of litigation which accompanied the increase of property was looked on as an evil to be checked in every possible method; and the method most relied on was that of limiting the number of legal practitioners. The well-known statute of 1455 (33 Hen. VI., c. 7, which is still in force) may be referred to as an instance. It recites a practice of contentious attorneys to stir up suits for their private profits, and enacts that there shall be but six common attorneys in Norfolk, six in Suffolk, and two in Norwich, to be elected and admitted by the chief-justice. As late as the year 1616 a rule was made, "that the number of attorneys of each court be viewed, to have them drawn to a competent number in each court, and the superfluous number to be removed." These various regulations, so far as they were enforced, could only have been detrimental to the public; and as regards the courts of King's Bench and Common Pleas, they seem not to have been long insisted on. As to the Exchequer, the principle of monopoly was continued in force down to the year 1830, until which time eighteen attorneys only were admitted to practise in it. As a consequence, that court was, before the year 1830, scarcely at all resorted to. Since that time more actions are commenced in it than in any other court. In the year 1632 a new principle was introduced into the common-law courts, and all persons wishing to be attorneys were required to serve an attorney under articles for six years (since reduced to five). The Six Clerks' Office, however, did not adopt this method until long after. They got over the difficulty by admitting under-clerks, afterwards called sworn clerks, to practise in their names, and they shared in some way or other the profits with them. In 1548 an inquisition was appointed, to inquire into the supposed exactions and abuses of the Court of Chancery, and the fees then payable for the business of this office. The presentment shows that all the fees payable for business done in this office were at that time payable to the Six Clerks; and it contains no allusion whatever to the under-clerks as being in any way known as officers of the court. They seem at that time to have held a position with regard to the Six Clerks quite analogous to that which the solicitors for a long period were under with regard to the sworn clerks, and to have been the real persons who prosecuted the causes. They must have been numerous, as in 1596 an order was made limiting the number that each Six-Clerk should be allowed to have under him. Soon after this the Six Clerks, instead of taking clients according to the clients' choice, agreed to divide the business coming from time to time into court among themselves alphabetically. This arrangement shows that the scheme of a limited number of legalised attorneys for the Court of Chancery had now entirely ceased to operate, and had been converted into a mere legal pretext to enable these officers to tax all who were driven to such Chancery Court for justice. This regulation for dividing the business was, after some years, set aside on petition of the Master of the Rolls to the crown, as a monopoly and a breach of the liberty of the subject. In 1630 the office of Six-Clerk was, if not a sinecure, at least an appointment of great value. From a ridiculous story told about Sir Julius Cæsar, the Master of the Rolls, in Clarendon's 'Rebellion,' it appears that the appointment at that time sold for so large a sum as 6000*l.* About this time the under or sworn clerks, or clerks in court (for all these names apply to them), began to be frequently mentioned in the orders regulating the court, and soon grew into a very important body. The under-clerks were the parties who knew the merits of the different causes, and were interested in getting the work done, so as to gain the fees from the clients. The Six Clerks had begun to sink into the lethargy of sinecurists. Many orders were made to spur them into activity, but all in vain.

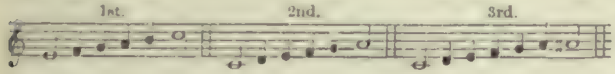
The Six Clerks, in a paper given in by them to the Chancery Commissioners of 1825, state that, "From the first establishment of the Six Clerks, up to the rebellion in the reign of King Charles I., many other important duties were attached to their office. During the usurpation, however, a part of the duties was assigned to certain new officers entitled the sworn clerks, who have ever since continued the execution thereof." The Six Clerks in this statement have fixed rather too early a date to the legal transfer. Great efforts were made for reform of legal procedure during the Commonwealth. Among others there was an ordinance for abolishing the office of Six-Clerk in 1654, but it terminated, with the other ordinances of the Commonwealth, at the Restoration, and the judges endeavoured vigorously to reinstate the Six Clerks in their old position. Lord Clarendon, in 1665, limited the under-clerks to twelve to each Six-Clerk; these under-clerks are sometimes referred to incidentally as the "attorneys of the parties," though it is strongly repeated that "the Six Clerks are the only attorneys of this court." In 1668 the Six Clerks submitted to their fate; an order was made fully recognising the under-clerks, and dividing the office-fees between them and the Six Clerks. The Six Clerks, having secured their own monopoly, had, by the year 1688, become the aggressors, and had schemed to increase their income by admitting other persons, as well as the sworn or under-clerks, to practise in their names. This was a bone of contention for many years. Before 1693 the under-clerks had obtained the privilege of filling up all the vacancies in the office by taking articled clerks themselves. From this time till their abolition, the office of Six-Clerk became a complete sinecure, and the Six Clerks were only mentioned in the court's annals with respect to the fees that they are entitled to demand from suitors. The office was abolished by Lord Brougham's Act, which enacted that vacancies should not be filled up till the number of Six Clerks was reduced to two. Nearly the same story has to be told over again with reference to the sworn clerks. For a long time these under-clerks were the principal solicitors of the court; and until the middle of the last century the chief business of the court was transacted by them without the intervention of a solicitor. The same principle of monopoly led with them to nearly the results that it did with their titular superiors. A vested right to fees in the various stages of equity proceedings brought about an inattention to business, which has led to the transfer of the prosecution of suits to the solicitors.

An effort was made in 1825 to get the offices of Six-Clerk and clerk in court abolished. It was broadly stated at this time by a solicitor of celebrity, that Mr. S. (a gentleman whose mind had failed him) was "quite as good a clerk in court after he was a lunatic;" and the expense of the office to the suitor was insisted on. Lord Eldon, however, saw no reason to interfere with these offices, and they remained condemned by the unanimous voice of the whole profession for many years longer. Ultimately they were abolished, the then holders of the offices receiving compensations so extravagant, that frequent attempts have been made, though unsuccessfully, to reopen the question.

For further information as to this office, the reader is referred to the case "Ex parte the Six Clerks," 3 Vesey's 'Reports,' 519; to the 'Reports of the Commissioners on the Offices of Courts of Justice' of 1816; to the 'Report of 1825 of the Chancery Commission;' to Beames's 'Orders of the Court of Chancery'; to pamphlets by Mr. Spence, Mr. Field, Mr. Merivale, and Mr. Wainewright; and to a powerful speech on Equity Reform, made in the end of the session of 1840, by Mr. Pemberton (now Lord Kingsdown), which was afterwards published in a separate form.

SIXTH, a musical interval, a concord, the ratio of which is 5 : 3. [CONCORD; HARMONY.]

Of the Sixth there are three kinds: the *Minor Sixth*, the *Major Sixth*, and the *Extreme Sharp Sixth*. The first (E, C), is composed of three tones and two semitones; the second (C, A), of four tones and one semitone; the third (C, A♯), of four tones and two semitones. Ex. :—



SIZAR, a term used in the University of Cambridge for a class of students who are admitted on easier terms as to pecuniary matters than others. These pecuniary advantages arise from different sources in different colleges, and are of different value. Originally certain duties were required of the students so admitted approaching to the character of menial, but these have been long discontinued. A similar class of students at Oxford are called Servitors. The word Sizar is supposed to be derived from *size*, which is used in the University to denote an allowance of provisions at the college buttery; and that from the verb to *assize*, which is much the same as the modern *assess*, which means *apportion*.

SIZE. [GLUE MANUFACTURE.]

SKEW-BACK, in civil engineering, the course of masonry forming the abutment for the voussoirs of a segmental arch, or, in iron bridges, for the ribs. In the latter case a plate of cast-iron is usually laid upon the stone skew-backs, extending the whole width of the bridge, and forming a tie to the masonry. On account of the expansion and contraction of iron under changes of temperature, the ribs should not, especially in large arches, be fixed to their abutments. The ribs of Southwark Bridge, over the Thames, were originally bolted to the masonry of the piers; but it was found necessary, on this account, to detach them, during the progress of the works.

SKEW-BRIDGE, a bridge in which the passages over and under the arch intersect each other obliquely. In conducting a road or railway through a district in which there are many natural or artificial water-courses, or in making a canal through a country in which roads are frequent, such intersections very often occur. As, however, the construction of an oblique or skew arch is more difficult than that of one built at right angles, skew-bridges were seldom erected before the general introduction of railways; it being more usual to build the bridge at right angles, and to divert the course of the road or of the stream to accommodate it, as represented in *fig.* 1, in which *a b* is a stream crossed by the road, the general direction of which is indicated by the dotted line *c d*. In a railway, and sometimes in a common road or a canal, such a deviation from the straight line of direction is inadmissible, and it therefore becomes necessary to build the bridge obliquely, as represented in the plan, *fig.* 2. Where space and neatness do not require to be considered, an oblique arch may be avoided, either by building the bridge square with the upper passage, and making the span so wide as to allow the stream to pass under it without being diverted; or by building the arch square with the stream, and of sufficient length to allow the upper passage to take an oblique course over it; but either of these is a clumsy expedient, although well adapted for some situations. The arches or tunnels by which the North-Western railway is conducted under the Hampstead Road and Park Street, near the London terminus, are instances of the latter kind of construction; the length of the arches being such that they present faces square with the line of railway, notwithstanding the oblique direction of the roads over them. A similar case occurs at Denbigh Hall, on the same line, where the railway crosses over the London and Holyhead road at such an angle that the difference of direction is only 25°. In this case a long gallery is constructed under the railway, consisting of iron ribs or girders, resting upon walls built parallel with the turnpike road; the ribs, and consequently the faces of the bridge, being at right angles with it. This gallery is about two hundred feet long and thirty-four feet wide; and by its adoption, the necessity of building an oblique arch of eighty feet span was avoided. The necessity of increasing the span of an arch according to its degree of obliquity, by which the expense and difficulty are materially increased, is illustrated by *fig.* 3, the ground-plan of an oblique arch across a stream *a b*. Here it is evident that *c g* is the actual span of the arch; although *c d*, the breadth of the stream, would be the span of a straight arch, leaving the same width of passage underneath.

Fig. 1.

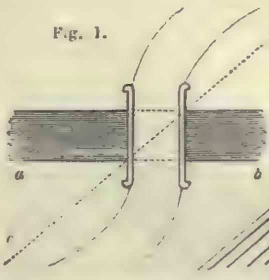


Fig. 2.

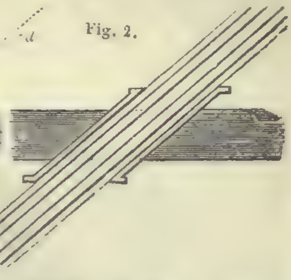
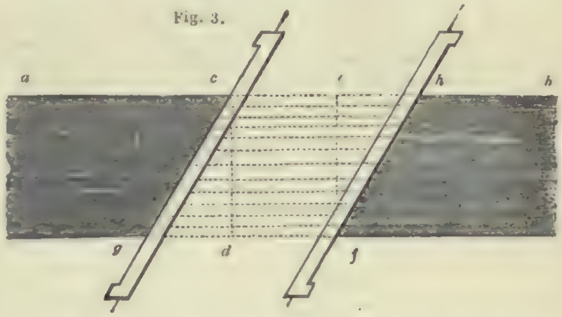
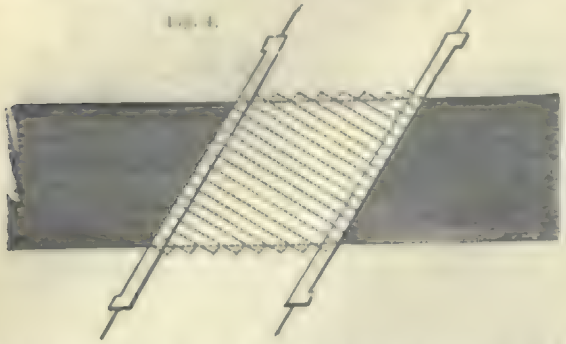


Fig. 3.



Very little is known respecting the origin of skew-bridges. It has been repeatedly asserted that those built by George Stephenson on the Liverpool and Manchester railway were the first erections of the kind; but this is certainly incorrect, there being some of earlier date even in Lancashire. A paper in the 'Transactions of the Institution of Civil Engineers,' vol i., p. 185, alludes to an oblique arch erected about the year 1530 by Nicolò, called "Il Tribolo," over the river Mugnone, near Porta Sangallo, at Florence. It appears however that the principle upon which such bridges should be constructed was too little understood to render an attempt at constructing them on a large scale advisable. The next information the writer has met with on the subject is contained in the article 'Oblique Arches,' in Rees's 'Cyclopædia;' an article which appears to have escaped the notice of modern writers on this branch of engineering science. It is written by an engineer named Chapman, who mentions oblique bridges as being in use prior to 1787, when he introduced a great improvement in their construction. Down to that time, as far as he was informed, such bridges had always been built in the same way as common square arches, the voussoirs being laid in courses parallel with the abutments. How very defective such an arch would be may be seen by reference to *fig.* 3, in which lines are drawn to indicate the direction of the courses. It is evident that here the portion *c d f e* is the only part of the arch supported by the abutments; the triangular portions *c d g* and *e f h* being sustained merely by the mortar, aided by being bonded with the rest of the masonry. This plan could therefore only be adopted for bridges of very slight obliquity, and even then with considerable risk. About the time mentioned above, Mr. Chapman was employed as engineer to the Kildare canal, a branch from the Grand Canal of Ireland to the town of Naas, on which it was desired to avoid diverting certain roads which had to be crossed. He was therefore led to look for some method of constructing oblique arches upon a sound principle, of which he considered that the leading feature must be that the joints of the voussoirs, whether of brick or stone, should be rectangular with the abutment, instead of being parallel with the face of the arch. Thus the courses, instead of taking the direction shown in *fig.* 3, were laid in the manner indicated in *fig.* 4. One of the first bridges built on this plan, the Finlay bridge, near Naas, crossed the canal at an angle of only 39°; the oblique span being 25 feet, and the height of the arch 5 feet 6 inches. Mr. Chapman observes that the lines on which the beds of the voussoirs lie are obviously spiral lines, and to this circumstance may be attributed much of the singular appearance of oblique arches. The Finlay bridge stood well, but the ingenious designer did not think it prudent in any other case to attempt so great a degree of obliquity, although he built several other bridges on the same principle, over the Grand Canal in Ireland, and over some wide drains in the East Riding of Yorkshire. He recommends carrying up the masonry as equally as possible from each abutment, in order to avoid unequal strains on the centering.

Fig. 4.

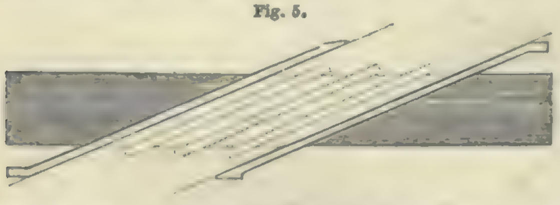


On the Liverpool and Manchester railway, out of rather more than sixty bridges, about one-fourth were built on the skew; one, built of stone, conducting the turnpike-road across the line at Rainhill, being at an angle of only 34°, by which the width of span is increased from 30 feet, the width of the railway from wall to wall, to 54 feet, the width on the oblique face of the arch. Skew-bridges have since become very common, and some have been erected of even greater obliquity. That at Box-moor, on the London and North-Western railway, was for long unrivalled for obliquity by any other brick arch. Its angle is 32°, the square span 21 feet, and the oblique span 39 feet. There are also brick arches of great obliquity on the Greenwich and Blackwall railways, but with their precise angles we are unacquainted; on the Paris and Rouen railway there is a skew-bridge of brickwork with stone bond courses of 28° of obliquity.

From Mr. Buck's treatise on oblique bridges, it appears that the difficulty of building skew-bridges increases with the obliquity of the angle from 90° to 45°, which is supposed to be the most hazardous angle for a semicircular arch; but that beyond that point, instead of increasing, it rather diminishes to about 25°, which appears to be about the natural limit for a semi-cylindrical arch. Mr. Buck, whose experience renders his opinion highly valuable, considers that oblique arches of the elliptical form should not be attempted, as they are deficient in stability, more difficult to execute, and more expensive than semicircular or segmental arches.

The construction of skew-bridges of iron or timber is comparatively simple, the ribs or girders of which such bridges are composed being of the usual construction, laid parallel with each other, but the end of each being in advance of that next preceding it. *Fig.* 5 represents the ground-plan of such a bridge, the dotted lines indicating the situation of the ribs upon which the platform is supported. The extraordinary iron bridge by which the Manchester and Birmingham railway is conducted over Fairfield-street, Manchester, at an angle of only 24½°, is a fine example of this kind of skew-bridge. It consists of six ribs, of rather more than 128 feet span, although the width of the street is only 48 feet, resting upon very massive abutments of masonry. The total weight of iron in this bridge, which is considered to be one of the finest iron arches ever built, is 540 tons. It was erected from the design of Mr. Buck, who has constructed several other oblique bridges of great size and very acute angles. Timber bridges, formed of trussed ribs or girders, are built on the same principle. One of very great obliquity, on the Sechill railway, is represented in the second series of Brees's 'Railway Practice.' A somewhat similar mode of constructing skew-bridges in brickwork was introduced by Mr. Gibbs on the Croydon railway. The Jolly Sailor bridge, which crosses over this line near Norwood, consisted originally of four separate ribs of brickwork, each forming an elliptical arch of 50 feet span, with a versed sine of 12 feet 6 inches, supporting a flat viaduct of Yorkshire flagstones. Each of these ribs, which were three feet wide on the transverse face, was built square, so that the brickwork was of the simplest kind; but by making the respective abutments project beyond each other according to the oblique direction of the railway, the ribs, taken collectively formed a skew-arch. In a bridge erected by Mr. Woodhouse on the line of the Midland Counties railway, the same principle is adopted, but the ribs are placed close together, so that no platform of flagstones is required.

Fig. 5.



SKIN, DISEASES OF. Most of the diseases of the skin are described in this work under their particular names. In this article we shall supply an arrangement of them, and a description of those which are not described under special heads. The following arrangement is that adopted by Rayer in his work on diseases of the skin:—

Class I. Inflammation of the Skin.

Order 1. *Exanthematous.*—Rubeola, Roseola, Scarlatina, Urticaria, Erythema, Erysipelas.
Order 2. *Bullous.*—Vesication, Ampullæ, Pemphigus, Rupia, Zona.
Order 3. *Vesiculous.*—Herpes, Psora, Eczema, Miliaria.
Order 4. *Pustulous.*—Varicella, Variola, Vaccinia, Vaccinella, Ecthyma, Cuperosa or Acne, Mentagra, Impetigo, Tinea, Artificial pustules.
Order 5. *Furunculous.*—Hordeolum, Furuncle, Anthrax.
Order 6. *Papulous.*—Strophulus, Lichen, Prurigo.
Order 7. *Tuberculous.*—Lupus, Cancer, Elephantiasis of the Greeks.
Order 8. *Squamous.*—Lepra, Psoriasis, Pityriasis [Scurf].
Order 9. *Linear.*—Fissures.
Order 10. *Gangrenous.*—Malign pustules, Carbuncle of plague.
Order 11. *Multiform.*—Burns, Frost-bite, Syphilitic eruptions.

Class II. Cutaneous and Subcutaneous Congestions, and Hæmorrhages.

Cyanosis, Vibices, Petechiæ, Purpura Hæmorrhagica, Ecchymosis, Dermatorrhagia.

Class III. Nervous Diseases of the Skin.

Exaltation, Diminution, Abolition of the sensibility of the skin, without appreciable alteration in the texture of this membrane.

Class IV. Alterations in the Colour of the Skin.

Order 1. *Decoloration.*—Leucopathia, partial, general; Chlorosis.
Order 2. *Accidental Colorations.*—Ephelis, Lentigo, Chloasma, Meladermis, Icterus, Nævus maculosus, Argentism.

Class V. Morbid Secretions.

Ephidrosis, Acne, Folliculous Tumours.

Class VI. Defects of Conformation and Texture.

Distention of the Skin, Cicatrices, Vegetations, Nævus hæmatodes, Subcutaneous vascular tumours, warts, pearly granulations; Corns, Ichthyosis, Horny appendages.

Diseases of the skin are very numerous and prevalent, but in the case of the majority which occur they arise from the neglect of some of the conditions necessary for the health of the skin. These conditions in general are, good nutritious food, which should be properly digested; a due amount of warm clothing, especially during changeable and cold weather; constant and regular exercise, so as to keep the skin as an excretory organ in perfect order; and daily ablution of every part of the body, without which and the occasional use of soap it is vain to expect to be free from many forms of skin disease.

The following are the diseases which appear to demand further notice:—

Eczema, Heat-eruption, is an inflammation of the skin, characterised at the outset by small non-contagious vesicles, the fluid of which is finally reabsorbed; by superficial excoriations, attended by a serous discharge, or by a squamous condition of the skin. This disease may be confined to one particular part of the body, or it may attack the whole surface. It may arise from a local cause, as from the direct rays of the sun, or from some general disturbance of the system. The vesicles may be only few, and the surrounding skin only slightly inflamed and confined to a very limited surface, or the vesicles may be numerous, the excoriations painful, the surface attacked extensive, and the tendency to inflammatory action in the skin so strong as to produce pustules instead of vesicles. Such are the characters of the three forms of eczema usually described by writers on diseases of the skin.—*E. solaris*, *E. rubrum*, *E. impetiginoides*. Eczema is more likely to be confounded with itch than any other disease, from which it may be distinguished by its non-contagiousness and the very different parts of the tegumentary system which it occupies.

There is a form of eczema which comes on from the exhibition of mercury and the external application of other medicines, and which frequently arises from the carelessness of the person attacked, which is called *E. mercuriale*.

The treatment of eczema must be adapted to the causes which have produced it. According to the general state of health of the person attacked, the disease will be either acute or chronic. Slight cases of acute eczema require only a simple treatment; a light diet, saline purgatives, and cooling or emollient applications to the part being all that is required. In some cases the inflammation is great and the pain intense, and where this occurs bleeding and a more active general treatment should be had recourse to. Chronic eczema is much more difficult to treat. The general health demands attention, and alteratives and tonics, according to circumstances, are demanded. Astringent lotions and ointments, such as the preparations of silver, zinc, alum, &c., may be used; sulphurous baths, and various mineral waters have also been recommended in old chronic cases of this disease. The tincture of cantharides and the preparations of arsenic have also been employed in the chronic forms of eczema.

Miliaria (Febris miliaris, Miliary Eruption) is also a vesiculous disease of the skin, and is described as contagious. It is accompanied with inflammation of the gastro-intestinal mucous membrane, and is accompanied by profuse sweating. Miliaria as an epidemic and independent disease is only seen between the 43rd and 49th degrees of latitude, and its existence has been doubted by some nosologists. It frequently accompanies other diseases, and retires with the cessation of the disease which it attends. When the fever accompanying it is slight it requires little treatment. Gentle purgatives and demulcents will be found sufficient. In the epidemic form, however, it is often a formidable disease, and requires the same treatment as other epidemic contagious fevers.

Rupia is a bullous disease accompanied with small bullæ, the bases of which are inflamed. The bullæ are not numerous but flat and full of a serous fluid, which becomes thick, puriform, or sanguinolent, and drying up forms blackish thin or prominent crusts. It is commonly developed on the legs, sometimes on the loins or thighs. It attacks children that are of a delicate constitution, and persons weakened by other diseases. The scrofulous are peculiarly liable to it, and it comes on after hard living, insufficient food exposure to cold, and vicious courses of life. It is generally indicative of an imperfect state of nutrition, and the treatment consists not so much in applications to the diseased skin, as in giving tone to the system by nutritious food, and tonic and alterative medicines.

Ecthyma (Pustulous Scale) is a non-contagious inflammation characterised by large pustules raised upon a hard circular base of a bright red colour. The pustules are of the largest size, the *phlyzaciæ* of Willan, so that ecthyma bears the same relation to pustular diseases that rupia does to vesicular ones. In some stages in fact it is difficult to distinguish one of these diseases from another. Willan describes four varieties of ecthyma, but Rayer recognises but two, acute ecthyma and chronic ecthyma. Acute ecthyma is a comparatively rare disease; it generally appears on the neck and shoulders, and runs its course in a few days. This form requires little treatment; light diet, diluent drinks, mild purgatives, and warm or cold applications to the part will suffice.

In chronic ecthyma the same kind of pustules appear, which discharge their contents in the course of two or three days, leaving behind them thick brown adherent crusts, which sometimes fall off, leaving an ulcer behind, but more frequently leaving a cicatrix. This form of the disease comes on in scrofulous and debilitated subjects, and is frequently modified by a syphilitic taint. Just in proportion to the intensity of the constitutional derangement will be the duration and extent of the disease. In its treatment the general health must be especially attended to; it is more a disease indicating a want of action than increased action, and alteratives, tonics, nutritious diet, change of air, and sea-bathing are more beneficial than the opposite kind of treatment.

Acne (Gutta rosacea, Rose-drop) is a chronic inflammation of the skin characterised by an eruption of small pustules surrounded by a hard and inflamed base. They are generally observed on the cheeks, nose, and forehead, and sometimes on the ears and neck. The pustules are sometimes single, constituting the simple form of the disease; at other times they become hardened and the whole skin becomes red, when the disease has different designations. This disease has its origin in the oil-tubes, and arises from an obstruction to the performance of their functions, which produces inflammation. The oil tubes of the face are very liable to obstruction from exposure to the air and other causes, and may be frequently observed tipped with a little black spot, and when pressed they give out a quantity of their oily secretion in the form of a little maggot. They were at one time supposed really to possess an independent animal life. Although this is not the case with the masses of oil in question, it is now known that a little acarus takes up its abode in these oil tubes, and is well known to zoologists under the name of Demodex Folliculorum. This little insect may then in some instances be the exciting cause of acne.

In the treatment of acne, regard must be had to the general health. It is frequently connected with a diseased state of the gastro-intestinal mucous system, which requires attention. Where it is connected with general debility from a rapid growth, or with a scrofulous constitution, tonics and alteratives with sea-bathing and regular exercise will be found of service. As external applications, the preparations of copper, zinc, and mercury, have been found most efficient. Where the face is much swelled and inflamed, fomentations will be of service previous to the use of the astringents.

Lichen is a papulous disease, characterised by the simultaneous or successive eruptions of red itching pimples, scattered or disposed in groups over the whole body. It is in the adult what Strophulus is in the child.

Lupus is a disease of the skin which, although it usually attacks the face, may appear on any other part of the body. It is generally attended with inflammatory action and with more or less enlargement of the parts attacked. It terminates in ulceration, which on account of its tendency to destroy the tissues which it attacks has got for this disease the name of "wolf." The ulcer is also called the "rodent ulcer," and the term *noli me tangere* has been applied to it. The disease may be superficial or it may penetrate more or less deeply, destroying whatever tissues it attacks. There is no doubt about the resemblance of this disease to cancer, especially that form called epithelial. It is, nevertheless, so strongly separated that it would be utterly inconsistent with the present knowledge of the nature of cancer to regard it as originating in the same state of the system. [CANCER.] The condition of the system and the nature of the ulceration rather point to the scrofulous diathesis as the originator of this disease.

In lupus no pathological elements can be discovered resembling those of cancer. If removed it does not recur, and there is no tendency to the production of the same disease in the lymphatics as in cancer. It is therefore a much less formidable disease. Nevertheless, the progress of the ulceration in many cases of lupus is sufficiently alarming and demands constant attention.

The treatment must be both local and general. In the local treatment removal by the knife is mostly out of the question, on account of the extent of surface involved. According to the tendency exhibited by the ulceration to spread a severe or mild system of cauterisation should be pursued. Sometimes the application of sulphate or acetate of zinc or nitrate of silver is sufficient to stimulate the parts to assume a healthy action; whilst at others more violent applications, as the chloride of zinc and tannic, nitric, or hydrochloric acids, are to be recommended. General treatment is frequently very efficacious, and this according to circumstances. In cases of tuberculosis of the system cod liver oil and quinine and iron may be used with advantage. In another set of cases arsenic has been found efficacious, whilst perhaps a larger number are benefited by preparations of iodine.

SKIN-DRESSING. [LEATHER MANUFACTURE.]

SKY is the name commonly applied to the infinite space which surrounds the earth, and of which the visible portion, above the horizon of a spectator on any part of the earth's surface, appears to have the form of a concave segment less than a hemisphere.

The earth is surrounded by the atmosphere, which is charged with vapours and terrestrial particles; and by the reflections which, in consequence, the rays of light experience in passing to the spectator, and the absorption which they undergo in their long transit of the atmosphere when the sun is near the horizon, the sky assumes the variously-coloured tints under which it is seen.

It is known from many experiments that *pure* air is devoid of colour; and the observations of M. de Saussure ('Voyages dans les Alpes,' tom. 4, p. 289) have established the fact, that, in an atmosphere free from vapours, such objects as mountains covered with snow, when seen by a spectator at a distance of 20 or 30 leagues from them, by light which is merely transmitted through the air, appear to be white: the same philosopher has observed, however, that at times when the sun is seen to set behind a mountain so covered, the blue rays reflected from the sky to the mountain, and from thence to the spectator, cause the mountain to assume a blue colour, the other light with which the mountain is illuminated not being strong enough to overpower the blue reflected rays.

When the sun has considerable elevation, the rays of light which pass through the earth's atmosphere almost perpendicularly to its surface, undergo scarcely any change of direction; but, with respect to the light from the sun which enters obliquely into the atmosphere, the violet and blue rays are partially arrested in their course, and are reflected in abundance to the earth; they thus, when the atmosphere is nearly free from clouds, give to the parts of the sky which are remote from the apparent place of the sun an azure tint.

The blue colour of the sky about the zenith increases in proportion as the sun is nearer the horizon; and, at the same time, the blue rays in the beams of light which traverse the atmosphere in directions nearly parallel to the horizon are absorbed, so that it is chiefly those of less refrangibility, such as the yellow and the red, that arrive at the eye of the spectator: in consequence of this the sky near the horizon, on the side which is towards the sun, appears to be highly tinted with those colours.

Many of the blue rays, after reflection from the upper parts of the atmosphere, are, however, absorbed in passing down to the earth; and further, it seems probable that in that portion of the reflection which takes place at a great elevation the blue rays are reflected in larger proportion compared with other colours than lower down; and hence it is that the blue tint of the sky is found to increase in intensity as the spectator ascends above the general surface of the earth. On the top of high mountains, or in balloons at great elevations, the proportion of blue rays which, after reflection in the atmosphere enter the eye is very great; and the blueness at length becomes a deep black ground on which the stars appear to shine at all times with as much lustre as at midnight on the earth, during the absence of the moon. It is hence evident that if it were not for the innumerable reflections of the light from the sun or moon, which take place in the atmosphere, total darkness would prevail from the instant of sun-set to that of sun-rise; and even during the day, darkness would ensue, so that the stars would become visible, every time that the sun is obscured by a cloud of sufficient density.

That the blue tint of the sky is caused by light reflected in the atmosphere, is abundantly evident from the fact that the light of the sky is found to be polarized, this quality in light being a result of its reflection. Sir David Brewster, who first made the observation, has moreover ascertained that the light of the sky consists of two parts, one blue and the other nearly without colour; and he discovered that these lights are polarized in different directions. ('Treatise on New Philosophical Instruments,' p. 349.)

The hypothesis that the azure colour of the sky is caused by reflections of blue rays, was at one time objected to on the ground that the shadows of opaque objects, placed on white paper and exposed to the sun's light, should always appear to be blue, since the part of the paper which is in shadow can only be visible by the light of the sky reflected from thence. This phenomenon is, in fact, frequently observed; but M. de Saussure, while admitting that he has often perceived the shadows of objects to be bluish in the mornings and evenings on the general surface of the earth, states that in Alpine regions, where the sky is intensely blue, the shadows of objects never appear to be so: he adds that, of fifty-nine observations made for the purpose of ascertaining the colours of shadows on the mountains, thirty-four showed them to be a pale violet, eighteen showed them to be black, six a pale blue, and once they appeared to be yellowish. It may be inferred, therefore, that shadows cast by opaque objects are so much affected by the colours of the neighbouring objects that a right judgment can scarcely be formed of the colour which they receive from the light of the sky. [ACCIDENTAL COLOURS.] To the like interference must be ascribed the variously-coloured shadows which were observed by M. Bouguer ('Essai d'Optique;' and M. Buffon, 'Mémoires de l'Académie des Sciences,' 1743.)

Between the tropics the transparency of the atmosphere is far greater than it is, in general, in regions beyond them towards the north or south; hence the sky there is almost always serene and intensely blue, while the clouds near the setting sun are brightly tinted with the prismatic colours. The skies of the south of Europe and some parts of North America are distinguished for their serenity and beauty; but, in these respects, they are said to be inferior to the skies over the islands in the Pacific Ocean.

For the description of an instrument invented in order to measure the intensity of the blue colour in the sky, see CYANOMETER.

SKYLIGHT. In the arts, the word *skylight* is sometimes used to express the frame or the window by which the direct light from the upper regions of the atmosphere is allowed to enter a room; at other times, and especially in cases connected with architectural jurisprudence, *skylight* is understood to mean the view of a portion of the atmosphere itself, or, in other words, an uninterrupted view of the portion of space to which a house proprietor is entitled. In this notice. attention will principally be directed to the former meaning of the word; for the latter meaning, and the various conditions attaching to it. see the articles EASEMENT, and LIGHTS, ANCIENT.

Skylights, in the ordinary sense may be divided into those which are placed in the roof or covering of the building, and into those which are placed in lanterns rising above the line of the roof; the former transmitting the light directly, the latter by means of vertical openings in their sides. In some cases. also, a building may be lighted by means of inclined skylights on the respective sides of the inclined roof over the flat ceiling of the room, and by a horizontal skylight in that ceiling; or, in other words, by a double skylight, as at the Madeleine at Paris; and in the enormous rooms of the spinning-factories a species of imperfect lantern skylight is used, in which one vertical glazed side and three obscure sides of a half pyramid are introduced. Small vertical windows, or, as they are technically called, "dormers," are occasionally used for the purpose of lighting domical or other buildings from the sky; but, strictly speaking, they must come under the category of windows. The hall of the Middle Temple of London, the dome of St. Paul's, and the Law Courts at Westminster, are illustrations of the use of lantern lights; the Pantheon at Rome. and the Pantheon in Oxford Street, London, are illustrations of the use of simple skylights; the other classes of skylights are principally used in commercial or manufacturing establishments, although the double ones are susceptible of being treated so as to produce very striking architectural effects. In mediæval structures, such as Westminster Hall, a portion of the light is obtained from the sky by means of dormers; but clerestory windows are much more frequently resorted to in the buildings of this period, when all the light cannot be obtained from the lower side walls.

The practical advantages of the respective kinds of skylights seem to be as follows:—In lantern lights, it is easy to provide for effecting ventilation at the same time and by the same means as those used for the admission of light. The windows in these cases are on the vertical sides of the lantern, and the top is covered by an opaque roof, usually formed of imperfectly conducting materials; any condensation of moisture from the internal atmosphere takes place, under these circumstances, on the vertical glass of the sides, and it can thence be easily removed. Skylights placed on the slope or at the top of a roof are exposed to considerable inconvenience from the condensation thus alluded to; and if they must be resorted to, it should be the object of the architect to keep them within the width susceptible of being covered by one sheet of glass; because if the length of the panes be such as to require the use of two sheets, the drops of water arising from condensation are likely to accumulate at the line of junction, and either to fall from thence or to remain under the lap, and if a frost should occur whilst water is there, it is very probable that the expansion of the water passing into ice may crack the glass. The introduction, by Sir J. Paxton, of the ridge and furrow system, has enabled modern architects to execute large plane surfaces of skylight; and it has, moreover, the advantage of being equally applicable to lantern or to flat lights of this description. Lantern lights must, it may be added, be placed upon the axis of the roof covering the room so lighted; skylights may be placed wherever it may be desired so to do; and in the large domes of modern buildings it is found that the lanterns are invariably placed over their centres, whilst the skylights let into the sides of roofs are disposed in the panels or segmental divisions in such wise as to cause the light to fall in the desired manner on the side walls. Lanterns diffuse light more equally over the areas they serve than lights let into the sides of the roof, but not more so than central skylights, such as those of the Pantheon; and for this reason it seems that, in sculpture galleries lighted from above, it would be preferable to introduce lanterns; whilst in picture galleries plane skylights on the slopes of the roof are the most advantageous, provided always that they do not receive the direct rays of the sun.

There are, indeed, few positions in which it is desirable to admit the sun's rays in rooms lighted from above; and wherever it is possible so to do, the light should be admitted from the north exclusively, because the glare and the reflection of the sun's rays affects the purity of colour of the objects exposed to them. In factories, and in show rooms, this law of excluding the direct sun's rays is carefully observed, and the skylights formed over them are usually made of the form above described; that is to say, as a section of a square pyramid, receiving light from its base which faces the north. The proportion of the surface for the transmission of light to the opaque part of the ceiling should be at least as 1 : 20; for in the Pantheon the diameter of the rotunda is about 141 feet, and that of the central light is 30 feet (or in the ratio of their areas as 1 to 22 nearly), and the light in that building would not be sufficient for the purposes of commerce or of manufacture. The height of the room will, however, affect this consideration; for the pencil of rays admitted through the skylight must be able to reach every portion of the inclosed area, and in a well-lighted room there should be no necessity for trusting to reflected rays. In the Pantheon, the height from the floor to the under side of the skylight is precisely equal to the diameter of the rotunda; and Fontana, in his 'Descrizione del Tempio Vaticano,' states that an examination of the most important buildings lighted by lanterns showed that the best proportions of the diameters of those structures to the diameters of the cupolas on which they rested were as 1 to 6, and that the height of such lanterns should be equal to half the diameter of the cupola; the whole of this height is not, however, devoted to the glazed part of the structure.

SLAKED LIME. [CALCIUM.]

SLANDER consists in the malicious speaking of such words as render the party who speaks them in the hearing of others liable to an action at the suit of the party to whom they apply. The mere speaking of the defamatory words instead of the writing of them is that which constitutes the difference between libel and slander. [LIBEL.]

Slander is of two kinds: one, which is actionable, as necessarily importing some general damage to the party who is slandered; the other, which is only actionable where it has actually caused some special damage. The first kind includes all such words as impute to a party the commission of some crime or misdemeanor for which he might legally be convicted and suffer punishment, as where one asserts that another has committed treason, or felony, or perjury. It also includes such words spoken of a party, with reference to his office, profession, or trade, as impute to him malpractice, incompetence, or bankruptcy; as of a magistrate, that he is partial, or corrupt; of a clergyman, that "he preaches lies in the pulpit;" of a barrister, that "he is a dunce, and will get nothing by the law;" and so on: or that tend to the disherison of a party, as where it is said of one who holds lands by descent, that he is illegitimate. Where a party is in possession of lands which he desires to sell, he may maintain an action against any one who slanders his title to the lands; as by stating that he is not the owner. With respect to the second kind of slander, the law will not allow damage to be inferred from words which are not in themselves actionable, even although the words are untrue and spoken maliciously. But if, in consequence of such words being so spoken, a party has actually sustained some injury, he may maintain an action of slander against the person who has uttered them. In such case the injury must be some certain actual loss, and it must also arise as a natural and lawful consequence of speaking the words. No unlawful act done by a third person, although he really was moved to do it by the words spoken, is such an injury as a party can recover for in this action. Thus, the loss of the society and entertainment of friends, of an appointment to some office, the breach of a marriage engagement caused by the slanderer's statement, are injuries for which a party may recover damages. But he can have no action because in consequence of such statement certain persons, to use an illustration of Lord Ellenborough's, "have thrown him into a horsepond by way of punishment for his supposed transgression."

With respect to both kinds of slander, it is immaterial in what way the charge is conveyed, whether by direct statement, or obliquely, as by question, epithet, or exclamation.

Two cannot join in bringing one action of slander, except in the case of husband and wife, or of partners for an injury done to their joint trade; nor can an action be brought against two, except a husband and wife, where slanderous words have been spoken by the wife.

In answer to an action of slander the defendant may plead that the words spoken were true, or that they were spoken in the course of a trial in a court of justice, and were pertinent to the case; or formed the subject of a confidential communication, as where a party on application *bonâ fide* states what he believes to be true relative to the character of a servant, or makes known facts merely for the purpose of honestly warning another in whom he is interested. (Com., *Dig.*, 'Action on the Case for Defamation,' D. 1, &c.)

SLATE-WORKING. Referring to SLATE, in NAT. HIST. DIV., for an account of the geological formation and structure of this valuable rock, we here add a few words concerning its practical working.

The quarrying of slate is comparatively easy, seeing that the lamellated structure enables the substance to split easily into layers. The usual processes are adopted for sawing and smoothing the slabs; but improved machines for these purposes have been introduced within the last few years. One machine has been invented for hollowing out thick blocks of slate into sinks and vessels, by means of cutters screwed to the ends of revolving shafts. By the use of peculiar tools, slate is now turned in the lathe. Mr. Mathews's apparatus for cutting and dressing slate consists of a frame, provided with arms, cutters, levers, toothed wheels, &c., in such a way that the cutters may be raised by a lever, and let fall with a sudden blow; and this in such a manner as to work the slate either into plain or fancy surfaces. Ordinary slate cannot very well be polished like other kinds of hard stone; it is rubbed smooth with an iron plate, sand, or gritstone, and water. Within the last quarter of a century, there has been a tendency to use slate for many purposes for which other substances used to be employed. The slate top of a billiard table is perhaps the best kind of work in this material. The best tables measure 12 feet by 6 feet; the top consists of four slabs of slate 6 feet by 3 feet, and one inch thick, ground on the lower surface planed on the upper, and adjusted edge to edge with the most scrupulous care. Pavements, cisterns, walls, partitions, &c., are now largely made in this material. "Enamelled slate" is used for table tops, chimney pieces, wash-stand tops, columns, pilasters, door furniture, monuments, mural tablets, &c.

What are called slate *pencils* are simply narrow slips of a soft kind of slate. Some of them are made to slide in wooden tubes or holders, by a propelling apparatus similar in character to that of certain of the ever-pointed pencils. Artificial slate pencils have been introduced, made of a mixture of alumina, French chalk, and soapstone.

The largest slate quarries in the United Kingdom are the Penrhyn, belonging to Colonel Pennant. These are briefly noticed under BANGOR, in GEOG. DIV.

M. Raphael Carmana has recently proposed the use of slate as a substitute for box-wood in wood engraving. He states that it is easily penetrated by the graver; that the finest lines are producible; and that slate is more durable than box under the action of the printing-press.

SLAVE, SLAVERY, SLAVE-TRADE. The word slavery has various acceptations, but its complete meaning is the condition of an individual who is the property of another or others. Such was the condition of the "servi," or slaves among the Romans and Greeks; such is still that of the slaves in Eastern countries, and that of the negro slaves in many parts of Africa and America. A mitigated form of this condition has existed up to the present time in the case of the serfs in Russia and Poland, though in the former, at least, it is about to be abolished; and still exists among a similar class in India and some other parts of Asia. The Russian and Polish serf is bound to the soil on which he is born; he may be sold or let with it, but cannot be sold away from it without his consent; he is obliged to work three or four days a-week for his master, who allows him a piece of land, which he cultivates. He can marry, and his wife and children are under his authority till they are of age. He can bequeath his chattels and savings at his death. His life is protected by the law. The slave of the Greek and Roman nations had none of these advantages, any more than the negro slave of our own times; he was bought and sold in the market, and was transferred at his owner's pleasure; he could acquire no property; all that he had was his master's; all the produce of his labour belonged to his master, who could inflict corporeal punishment upon him; he could not marry; and if he cohabited with a woman, he could be separated from her and his children at any time, and the woman and children sold. The distinction therefore between the slave and the serf is essential. The villeins (villani) of the middle ages were a kind of serfs, but their condition seems to have varied considerably according to times and localities. In the present article we treat only of the real slave of ancient and modern times.

Slavery, properly so called, appears to have been, from the earliest ages, the condition of a large proportion of mankind in almost every country, until times comparatively recent, when it has been gradually abolished by all Christian states, at least in Europe. The condition of slavery constitutes one great difference between ancient and modern society. Slavery existed among the Jews; it existed before Moses, in the time of the Patriarchs; and it existed, and still continues to exist, in many parts of Asia. The "servants" mentioned in Scripture history were mostly slaves: they were strangers, either taken prisoners in war or purchased from the neighbouring nations. They and their offspring were the property of their masters, who could sell them, and inflict upon them corporeal punishment, and even in some cases put them to death. But the Hebrews had also slaves of their own nation. These were men who sold themselves through poverty, or they were insolvent debtors, or men who had committed a theft, and had not the means of making restitution as required by the law, which was to double the amount, and in some cases much more. (Exod. xxii.) Not only the person of the debtor was liable to the claims of the creditor, but his right extended also to the debtor's wife and children. Moses regulated the condition of slavery. He drew a wide distinction between the alien slave and the native servant. The latter could not be a perpetual bondman, but might be redeemed; and if not redeemed, he became free on the completion of the seventh year of his servitude. Again, every fifty years the jubilee caused a general emancipation of all native servants.

The sources of the supply of slaves have been the same both in ancient and modern times. In ancient times all prisoners were reduced to slavery, being either distributed among the officers and men of the conquering army, or sold. When the early Æolian and Ionian colonies settled in the islands of the Ægean Sea, and on the coast of Asia Minor, it was a frequent practice with them to kill the adult males of the aboriginal population, and to keep the women and children. As, however, dealing in slaves became a profitable trade, the vanquished, instead of being killed, were sold, and this was so far an improvement. Another source of slavery was the practice of kidnapping men and women, especially young persons, who were seized on the coast, or enticed on board by the crews of piratical vessels. The Phœnicians, and the Etruscans or Tyrrhenians, had the character of being men-stealers; and also the Cretans, Cilicians, Rhodians and other maritime states. Another source was, sale of men, either by themselves, through poverty and distress, or by their relatives and superiors, as is done now by the petty African chiefs, who sell not only their prisoners, but their own subjects, and even their children, to the slave-dealers. Herodotus (v. 6) states that some of the Thracian tribes sold their children to foreign dealers.

Among the Greeks slavery existed from the heroic times, and the purchase and use of slaves are repeatedly mentioned by Homer. The labours of husbandry were performed in some instances by poor freemen for hire, but in most places, especially in the Doric states, by a class of bondmen, the descendants of the older inhabitants of the country, resembling the serfs of the middle ages, who lived upon and cultivated the lands which the conquering race had appropriated to themselves; they paid a rent to the respective proprietors, whom they also attended in war. They could not be put to death without trial, nor be sold out of the country, nor separated from their families; they could acquire property, and were often richer than their masters. Such were the Clarotæ of Crete, the Penestæ of Thessaly Proper, and the Helots of Sparta, who must not be confounded with the Periœci, or country inhabitants of Laconica in general, who were political subjects of the Doric community of Sparta, without however being bondmen. In the colonies of the Dorians beyond the limits of Greece, the condition of the conquered natives was often more degraded than that of the bondmen of the parent states, because the former were not Greeks, but barbarians, and they were reduced to the condition of slaves. Such was the case of the Kallirioi or Kallikurioi of Syracuse, and of the native Bithynians at Byzantium. At Heraclea in Pontus, the Mariandyni submitted to the Greeks on condition that they should not be sold beyond the borders, and that they should pay a fixed tribute to the ruling race.

The Doric states of Greece had few purchased slaves, but Athens, Corinth, and other commercial states had a large number, who were mostly natives of barbarous countries. The slave population in Attica has been variously estimated as to numbers, and it varied of course considerably at different periods; but it appears that in Athens, at least in the time of its greatest power, they were much more numerous than the freemen. From a fragment of Hyperides preserved by Suidas (*v.* ἀπεψηφίσατο), the number of slaves appears to have been at one time 150,000, who were employed in the fields and mines of Attica alone. Even the poorer citizens had a slave for their household affairs. The wealthier citizens had as many as fifty slaves to each family, and some had more. We read of philosophers keeping ten slaves. There were private slaves belonging to families, and public slaves belonging to the community or state. The latter were employed on board the fleet in the docks and arsenal, and in the construction of public buildings and roads.

Slaves were dealt with like any other property: they worked either on their master's account or on their own, in which latter case they paid a certain sum to their master; or they were let out on hire as servants or workmen, or sent to serve in the navy of the state, the master receiving payment for their services. Mines were worked by slaves, some of whom belonged to the lessees of the mine, and the rest were hired from the great slave proprietors, to whom the lessees paid a rent of so much a head, besides providing for the maintenance of the slave, which was no great matter. They worked in chains, and many of them died from the effect of the unwholesome atmosphere. Nicias the elder had 1000 slaves in the mines of Laurium; others had several hundreds, whom they let to the contractors for an obolus a-day each. At one time the mining slaves of Attica murdered their guards, took possession of the fortifications of Sunium, and ravaged the surrounding country. (Fragment of Posidonius's Continuation of Polybius; see Boeckh's 'Public Economy of Athens,' b. i.) The thirty-two or thirty-three iron-workers or sword-cutlers of Demosthenes annually produced a net profit of thirty minæ, their purchase value being 190 minæ; whilst his twenty chair-makers, whose value was estimated at 40 minæ, brought in a net profit of 12 minæ. (Demosthenes 'Against Aphobus,' i.)

The ancients were so habituated to the sight of slavery, that none of the Greek philosophers make any objection to its existence. Plato, in his 'Perfect State,' desires only that no Greeks should be made slaves.

The Etruscans and other ancient Italian nations had slaves, as is proved by those of Vulsinii revolting againt their masters, and by the tradition that the Bruttii were runaway slaves of the Lucanians. The Campanians had both slaves and gladiators previous to the Roman conquest. But the Romans, by their system of continual war, caused an enormous influx of slaves into Italy, where the slave population at last nearly superseded the free labourers.

The Roman system of slavery had peculiarities which distinguished it from that of Greece. The Greeks considered slavery to be founded on permanent diversities in the races of men. (Aristotle, 'Polit.,' i. 5.) The Romans admitted in principle that all men were originally free ('Instit.,' i., tit. 2) by natural law (jure naturali), and they ascribed the power of masters over their slaves entirely to the will of society, to the "jus gentium," if the slaves were captives taken in war, whom the conquerors, instead of killing them, as they might have done, spared for the purpose of selling them, or to the "jus civile," when a man of full age sold himself. It was a rule of Roman law, that the offspring of a slave woman followed the condition of the mother. ('Instit.,' i., tit. 3.) Emancipation was much more frequent at Rome than in Greece: the emancipated slave became a freedman (libertus), but whether he became a Roman citizen, a Latinus, or a Dediticius, depended on circumstances. If the manumitted slave was above thirty years of age, if he was the Quiritarian property of his manumittor, and if he was manumitted in due form, he became a Roman citizen. (Gaius, i. 17.) At Athens, on the contrary, emancipation from the dominion of the master was seldom followed by the privileges of citizenship even to a limited extent, and these privileges could only be conferred by public authority. It is true, that at Rome, under the empire, from the enactment of the Lex Ælia Sentia, passed in the time of Augustus, there were restrictions, in point of number, upon the master's power of freeing his bondmen and raising them to the rank of Roman citizens; still in every age there was a prospect to the slave of being able to obtain his freedom.

Slaves were not considered members of the community: they had no rights, and were in most respects considered as things or chattels. They could neither sue nor be sued. When an alleged slave claimed his freedom on the plea of unjust detention, he was obliged to have a free protector, to sue for him, until Justinian ('Code,' vii., tit. 1, 7, 'De adsertione tollenda') dispensed with that formality. Slaves had no connubium, that is, they could not contract a Roman marriage; their union with a person of their own rank was styled contubernium; and even the Christian church for several centuries did not declare the validity of slave marriages. At last the Emperor Basilius allowed slaves to marry and receive the blessing of the priest, and Alexius Comnenus renewed the permission. As slaves had no connubium, they had not the parental power (patria potestas) over their offspring, no ties of blood were recognised among them, except with respect to incest and parricide, which were considered as crimes by the law of nature. Though slaves were incapable of holding property, they were not incapacitated from acquiring property, but what they did acquire belonged to their masters. They were allowed to enjoy property as their own, "peculium," consisting sometimes of other slaves; but they held it only by permission, and any legal proceedings connected with it could only be conducted in the name of the master, who was the only legal proprietor. Until the latter period of the republic, slaves, and even freedmen, were not admitted into the ranks of the army. In cases of urgent public danger, such as after the defeat of Cannæ, slaves were purchased by the state and sent to the army, and if they behaved well they were emancipated. (Livy, xxii. 57, and xxiv. 14 16.)

They were not, however, denied the rites of burial, and numerous inscriptions attest that monuments were often erected to the memory of deceased slaves by their masters, their fellows, or friends, some of which bear the letters D. M., "Diis Manibus." Slaves were often buried in the family burying-place of their masters. The "sepulchretum" or burial-vault of the slaves and freedmen of Augustus and his wife Livia, discovered in 1726 near the Via Appia, and which has been illustrated by Bianchini and Gori, and another in the same neighbourhood also belonging to the household of the early Cæsars, and containing at least 3000 urns, with numerous inscriptions, which have been illustrated by Fabretti, throw much light upon the condition and domestic habits of Roman slaves in the service of great families.

With regard to the classification and occupations of slaves, the first division was into public and private. Public slaves were those which belonged to the state or to public bodies, such as provinces, municipia, collegia, decuriæ, &c., or to the emperor in his sovereign capacity, and employed in public duties, and not attached to his household or private estate. Public slaves were either derived from the share of captives taken in war which was reserved for the community or state, or were acquired by purchase and other civil process. Public slaves of an inferior description were engaged as rowers on board the fleet, or in the construction and repair of roads and national buildings. Those of a superior description were employed as keepers of public buildings, prisons, and other property of the state, or to attend magistrates, priests, and other public officers, as watchmen, lictors, executioners, watermen, scavengers, &c.

Private slaves were generally distributed into urban and rustic; the former served in the town houses, and the others in the country. Long lists of the different duties performed by slaves of each class are given by Pignorius, 'De Servis et eorum apud Veteres Ministeriis,' Amsterdam, 1674; Popma, 'De Operis Servorum,' ibid, 1672; and Blair, 'An Inquiry into the State of Slavery amongst the Romans,' Edinburgh, 1833, which is a very useful little book. For all the necessities of domestic life, agriculture, and handicraft, and for all the imaginable luxuries of a refined and licentious people, there was a corresponding denomination of slaves. Large sums were occasionally paid for slaves of certain peculiar kinds, some of which we should consider the least useful. Eunuchs were always very dear. A "morio," or fool, was sometimes sold for 20,000 nummi, or about 160*l*. Dwarfs and giants were also in great request. Marcus Antonius paid for a pair of handsome youths 200 sestertia, or 1600*l*. Actors and actresses, and dancers, sold very dear, as well as females of great personal attractions who were likely to bring in great gains to their owners by prostitution. A good cook was valued at four talents, or 772*l*. Medical men, grammarians, amanuenses, anagnostæ, or readers, and short-hand writers, were in considerable request. With regard to ordinary slaves, the price varied from 50*l*. to 20*l*., according to their abilities and other circumstances. After a victorious campaign, when thousands of captives were sold at once on the spot for the purpose of prize-money, to the slave-dealers who followed the armies, the price sank very low. Thus, in the camp of Lucullus in Pontus (Plutarch, 'Lucullus,' c. 14) slaves were sold for four drachmæ, or two shillings and sevenpence, a head; but the same slaves, if brought to the Roman market, would fetch a much higher price. Home-born slaves, distinguished by the name of "vernæ," in contradistinction to "servi empti," or "venales," or imported slaves, were generally treated with greater indulgence by their masters in whose families they had been brought up; and they generally were considered of inferior value to the imported slaves, being considered as spoilt and troublesome. The number of slaves born in Roman families appears at all times to have been far inferior to that of the imported slaves.

There was a brisk trade in slaves carried on from the coasts of Africa, the Euxine, Syria, and Asia Minor. The island of Delos was at one time a great mart for slaves, who were imported thither by the Cilician pirates. (Strabo, p. 668, Casaub.) The Illyrians procured numerous slaves for the Italian market, whom they bought or stole from the barbarous tribes in their neighbourhood. But the chief supply of slaves was derived from Asia and Africa. In most countries it was customary for indigent parents to sell their children to slave-dealers. Criminals were also in certain cases condemned to slavery, like the galley-slaves of our own times.

Both law and custom forbade prisoners taken in civil wars, especially in Italy, to be dealt with as slaves; and this was perhaps one reason of the wholesale massacres of captives by Sulla and the Triumviri. In the war between the party of Otho and Vitellius, Antonius, who commanded the army of the latter, having taken Cremona, ordered that none of the captives should be detained, upon which the soldiers began to kill those who were not privately ransomed by their friends.

In the later period of the empire free-born persons of low condition were glad to secure a subsistence by labour on the estates of the great landowners, to which, after a continued residence for thirty years, they and their families became bound by a tacit agreement under the name of Coloni, Rustici, Adscriptitii, &c. The phrase "servi terræ," which is applied to them, shows their connection with the soil. They could marry, which slaves could not. Though they bear a considerable resemblance to the serfs and villeins (villani) of the middle ages, yet there are some important points of difference, and there is no evidence of any historical connection between the Coloni and Villani. The subject of the Coloni is discussed by Savigny, 'Ueber den Römischen Colonat; Zeitschrift für Geschicht. Rechtswissenschaft,' vol. vi.

The customary allowance of food for a slave appears to have been four Roman bushels, "modii," of corn, mostly "far," per month for country slaves, and one Roman libra or pound daily for those in town. Salt and oil were occasionally allowed, as well as weak wine. Neither meat nor vegetables formed part of their regular allowance; but they got, according to seasons, fruit, such as figs, olives, apples, pears, &c. (Cato, Columella and Varro.) Labourers and artisans in the country were shut up at night in a house ("ergastulum"), in which each slave appears to have had a separate cell. Columella adverts to some distinction between the ergastulum for ordinary labourers and that for ill-behaved slaves, which latter was in fact a prison, often under ground; but generally speaking the ergastula in the later times of the republic and under the empire appear to have been no better than prisons in which freemen were sometimes confined after being kidnapped. The men often worked in chains. The overseers of farms and herdsmen had separate cabins allotted to them. Slaves enjoyed relaxation from toil on certain festivities, such as the Saturnalia.

The number of slaves possessed by the wealthy Romans was enormous. Some individuals are said to have possessed 10,000 slaves. Scaurus possessed above 4000 domestic and as many rustic slaves. In the reign of Augustus, a freedman who had sustained great losses during the civil wars left 4116 slaves, besides other property.

A master had, as a general rule, the power of manumitting his slave, and this he could effect in several forms, by vindicta, census, or by testamentum. The Lex Ælia Sentia, as already mentioned, laid various restrictions on manumission. Among other things it prevented persons under twenty years of age from manumitting a slave except by the vindicta, and with the approbation of the consilium, which at Rome consisted of five senators and five Roman equites of legal age (puberes), and in the provinces consisted of twenty recuperatores, who were Roman citizens. (Gaius, i. 20, 38.) The Lex Ælia Sentia also made all manumissions void which were effected to cheat creditors or defraud patrons of their rights. The Lex Furia Caninia, which was passed about A.D. 7, limited the whole number of slaves who could be manumitted by testament to 100, and when a man had fewer than 500 slaves, it determined by a scale the number that he could manumit. This lex only applied to manumission by testament. (Gaius, i. 42, &c.)

In the earlier ages of the Republic, slaves were not very numerous, and were chiefly employed in household offices or as mechanics in the towns. But after the conquests of Rome spread beyond the limits of Italy the influx of captives was so great, and their price fell so low, that they were looked upon as a cheap and easily renewed commodity, and treated as such. The condition of the Roman slave, generally speaking, became worse in the later ages of the republic; and many of the emperors, even some of the worst of them, interfered on behalf of the slave. Augustus established courts for the trial of slaves who were charged with serious offences, intending thus to supersede arbitrary punishment by the masters, but the law was not made obligatory upon the masters to bring their slaves before the courts, and it was often evaded. By a law passed in the time of Claudius, a master who exposed his sick or infirm slaves forfeited all right over them in the event of their recovery. The Lex Petronia, probably passed in the time of Augustus, or in the reign of Nero, prohibited masters from compelling their slaves to fight with wild beasts, except with the consent of the judicial authorities, and on a sufficient case being made out against the slave. Domitian forbade the mutilation of slaves. Hadrian suppressed the ergastula, or private prisons for the confinement of slaves; he also restrained proprietors from selling their slaves to keepers of gladiators, or to brothel-keepers, except as a punishment, in which case the sanction of a judge (judex) was required. Antoninus Pius adopted an old law of the Athenians by which the judge who should be satisfied of a slave being cruelly treated by his owner, had power to oblige the owner to sell him to some other person. The judge, however, was left entirely to his own discretion in determining what measure of harshness in the owner should be a proper ground for judicial interposition. Septimius Severus forbade the forcible subjection of slaves to prostitution. The Christian emperors went further in protecting the persons of slaves. Constantine placed the wilful murder of a slave on a level with that of a freeman; and Justinian confirmed this law, including within its provisions cases of slaves who died under excessive punishment. Constantine made also two laws, both nearly in the same words, to prevent the forcible separation of the members of servile families by sale or partition of property. One of the laws, dated A.D 334, was retained by Justinian in his code. The church also powerfully interfered for the protection of slaves, by threatening excommunication against owners who put to death their slaves without the consent of the judge; and by affording asylum within sacred precincts to slaves from the anger of unmerciful masters. A law of Theodosius I. authorised a slave who had taken refuge in a church to call for the protection of the judge, that he might proceed unmolested to his tribunal in order that his case might be investigated. After Christianity became the predominant religion in the Roman world, it exercised in various ways a beneficial influence upon the condition of the slaves, without, however, interfering, at least for centuries, with the institution of slavery itself. Even the laws of the Christian emperors which abolished the master's power of life and death over his slave were long evaded. Salvianus ('De Gubernatione Dei,' iv.) informs us that in the provinces of Gaul, in the 5th century, masters still fancied that they had a right to put their slaves to death. Macrobius ('Saturn.', i. 11) makes one of his interlocutors, though a heathen, expatiate with great eloquence on the cruel and unjust treatment of slaves. In Spain, in the early period of the Visigothic kings, the practice of putting slaves to death still existed, for in the 'Foro Judicum' (b. vi., tit. 5) it is said that as some cruel masters in the impetuosity of their pride put to death their slaves without reason, it is enacted that a public and regular trial shall take place previous to their condemnation. Several laws and ecclesiastical canons forbade the sale of Christians as slaves to Jews or Saracens and other unbelievers.

The northern tribes which invaded the Western empire had their own slaves, who were chiefly Slavonian captives, distinct from the slaves of the Romans or conquered inhabitants. In course of time, however, the various classes of slaves merged into one class, that of the "adscripti glebæ," or serfs of the middle ages, and the institution of Roman slavery in its unmitigated form became obliterated. The precise period of this change cannot be fixed; it took place at various times in different countries. Slaves were exported from Britain to the Continent in the Saxon period. Giraldus Cambrensis, William of Malmesbury, and others, accuse the Anglo-Saxons of selling their female servants and even their children to strangers, and especially to the Irish, and the practice continued even after the Norman conquest. In the canons of a council held at London, A.D. 1102, it is said, "Let no one from henceforth presume to carry on that wicked traffic by which men in England have been hitherto sold like brute animals." (Wilkin's 'Concilia,' i. p. 383.)

But although the traffic in slaves ceased among the Christian nations of Europe, it continued to be carried on by the Venetians across the Mediterranean in the age of the Crusades. The Venetians supplied the markets of the Saracens with slaves purchased from the Slavonian tribes which bordered on the Adriatic. Besides, as personal slavery and the traffic in slaves continued in all Mohammedan countries, Christian captives taken by Mussulmans were sold in the markets of Asia and Northern Africa, and have continued to be sold till within our own times, when Christian slavery has been abolished in Barbary, Egypt, and the Ottoman empire, by the interference of the Christian powers, the emancipation of Greece, and the conquest of Algiers by the French.

With the discovery of America, a new description of slavery and slave-trade arose. Christian nations purchased African negroes for the purpose of employing them in the mines and plantations of the New World. The natives of America were too weak and too indolent to undergo the hard work which their Spanish task-masters exacted of them, and they died in great numbers. Las Casas, a Dominican, advocated with a persevering energy before the court of Spain the cause of the American aborigines, and reprobated the system of the "repartimientos," by which they were distributed in lots like cattle among their new masters. But it was necessary for the settlements to be made profitable in order to satisfy the conquerors, and it was suggested that negroes from Africa, a more robust and active race than the American Indians, might be substituted for them. It was stated that an able-bodied negro could do as much work as four Indians. The Portuguese were at that time possessed of a great part of the coast of Africa, where they easily obtained by force or barter a considerable number of slaves. The trade in slaves among the nations of Africa had existed from time immemorial. It had been carried on in ancient times: the Garamantes used to supply the slave-dealers of Carthage, Cyrene, and Egypt with black slaves which they brought from the interior. The demand for slaves by the Portuguese in the Atlantic harbours gave the trade a fresh direction. The petty chiefs of the interior made predatory incursions into each other's territories, and sold their captives, and sometimes their own subjects, to the European traders. The first negroes were imported by the Portuguese from Africa to the West Indies in 1503, and in 1511 Ferdinand the Catholic allowed a larger importation. These, however, were private and partial speculations; it is said that Cardinal Ximenes was opposed to the trade because he considered it unjust. Charles V., however, being pressed on one side by the demand for labour in the American settlements, and on the other by Las Casas and others who pleaded the cause of the Indian natives, granted to one of his Flemish courtiers the exclusive privilege of importing 4000 blacks to the West Indies. The Fleming sold his privilege for 25,000 ducats to some Genoese merchants, who organised a regular slave-trade between Africa and America. As the European settlements in America increased and extended, the demand for slaves also increased; and all European nations who had colonies in America shared in the slave-trade. It is generally understood that the slaves of the Spaniards, especially in Continental America, were the best treated of all. But the negro slaves in general were exactly in the same condition as the Roman slaves of old, being saleable, and punishable at the will of their owners Restrictions, however, were gradually introduced by the laws of the respective states, in order to protect the life of the negro slave against the caprice or brutality of his owner. In the British colonies, especially in the latter part of the last century and the beginning of the present, much was done by the legislature; courts were established to hear the complaints of the slaves, flogging of females was forbidden, the punishment of males was also limited within certain bounds, and the condition of the slave population was greatly ameliorated. Still the advocates of emancipation objected to the principle of slavery as being unjust and unchristian; and they also appealed to experience to show that a human being cannot be safely trusted solely to the mercy of another.

But long before they attempted to emancipate the slaves, the efforts of philanthropists were directed to abolish the slave traffic, which desolated Africa, wholly prevented its advance in civilisation, and encouraged the maltreatment of the negroes in the colonies, by affording an unlimited supply, and making it not the planter's interest to keep up his stock in the natural way. The attention of mankind was first effectually awakened to the horrors of this trade by Thomas Clarkson. His labours, with the aid of the zealous men, chiefly Quakers, who early joined him, prepared the way for Mr. Wilberforce, who brought the subject before parliament in 1788, and although, after his notice, the motion, owing to his accidental illness, was first brought forward by Mr. Pitt, Mr. Wilberforce was throughout the great parliamentary leader in the cause, powerfully supported in the country by Thomas Clarkson and others, as Richard Phillips, George Harrison, William Allen, all of the Society of Friends, Mr. Stephen, who had been in the West Indies as a barrister, and Mr. Z. Macaulay, who had been governor of Sierra Leone, and had also resided in Jamaica. A bill was first carried (brought in by Sir W. Dolben) to regulate the trade until it could be abolished, and this in some degree diminished the horrors of the middle passage. But the question of abolition was repeatedly defeated, until 1804, when Mr. Wilberforce first carried the bill through the Commons; it was thrown out in the Lords, and next year it was again lost even in the Commons. Meanwhile the capture of the foreign colonies, especially the Dutch, during the war, frightfully increased the amount of the trade, by opening these settlements to British capital; and at one time the whole importation of slaves by British vessels amounted to nearly 60,000 yearly, of which about a third was for the supply of our old colonies. At length, in 1805, an order in council prohibited the slave-trade in the conquered colonies. Next year the administration of Lord Grenville and Mr. Fox carried a bill through, prohibiting British subjects from engaging in the trade for supplying either foreign settlements or the conquered colonies. A resolution moved by Mr. Fox, the last time he took any part in public debate, was also carried in 1806, pledging the Commons to a total abolition of the trade early next session, and this was, on Lord Grenville's motion, adopted by the Lords. Accordingly next year the General Abolition Bill was brought in by Lord Howick (afterwards Earl Grey), and being passed by both houses, received the royal assent on the 25th of March, 1807. This act prohibited slave-trading from and after the 1st of January, 1808; but as it only subjected offenders to pecuniary penalties, it was found that something more was required to put down a traffic the gains of which were so great as to cover all losses by capture. In 1810 the House of Commons, on the motion of Mr. Brougham, passed unanimously a resolution, pledging itself early next session effectually to prevent "such daring violations of the law;" and he next year carried a bill making slave-trading felony, punishable by fourteen years' transportation, or imprisonment with hard labour. In 1824 the laws relating to the slave-trade were consolidated, and it was further declared to be piracy, and punishable capitally, if committed within the Admiralty jurisdiction. In 1837 this was changed to transportation for life, by the acts diminishing the number of capital punishments. Since the Felony Act of 1811, the British colonies have entirely ceased to have any concern in this traffic. If any British subjects have engaged in it, or any British capital has been embarked in it, the offence has been committed in the foreign trade.

The Duke of Wellington, while ambassador at Paris in 1814, used every effort to obtain from the restored Bourbon government a prohibition of the traffic in slaves; but the French West Indian interest and commercial jealousy of England frustrated all his attempts. The first French law abolishing the slave-trade was a decree issued by Napoleon on the 29th of March, 1815, during the Hundred Days, after his return from Elba. It prohibited any vessel from fitting out for the trade, either in the ports of France or in those of her colonies; and the introduction or sale in the French colonies of any negro obtained by the trade, whether carried on by French subjects or foreigners. The influence of Great Britain was again strenuously exerted at the peace in 1815, to obtain the concurrence of foreign powers in the abolition; and the object has been steadily kept in view by this country, and every opportunity of forwarding it taken advantage of, down to the present time. The consequence has been that now nearly all the powers in Europe and America have passed laws, or entered into treaties, prohibiting the traffic.

To the General Treaty signed by the representatives of Austria, France, Great Britain, Portugal, Prussia, Russia, Spain, and Sweden, assembled in Congress at Vienna, on the 9th of June, 1815, was annexed, as having the same force as if textually inserted, a Declaration, signed at the same place by the Plenipotentiaries of certain of the powers, on the 8th of February preceding, to the following effect:—that seeing several European governments had already, virtually, come to the resolution of putting a stop to the slave trade, and that, successively, all the powers possessing colonies in different parts of the world had acknowledged, either by legislative acts, or by treaties or other formal engagements, the duty and necessity of abolishing it; and that by a separate article of the late treaty of Paris (30th May, 1814), Great Britain and France had engaged to unite their efforts at this Congress of Vienna to induce all the powers of Christendom to proclaim its universal and definitive abolition; the members of the Congress now declared, in the face of Europe, that they were animated with the sincere desire of concurring in the most prompt and effectual execution of this measure by all the means at their disposal. And this Declaration was renewed by the plenipotentiaries of Austria, France, Great Britain, Prussia, and Russia, assembled in Congress at Verona, in resolutions adopted in a conference held on the 28th of November, 1822; in which, however, it is admitted that, "notwithstanding this declaration, and in spite of the legislative measures which have in consequence been adopted in various countries, and of the several treaties concluded since that period between the maritime powers, this commerce, solemnly proscribed, has continued to this very day; that it has gained in activity what it may have lost in extent; that it has even taken a still more odious character, and more dreadful from the nature of the means to which those who carry it on are compelled to have recourse."

The following will be found, we believe, to be a correct and complete list of the treaties and conventions for the suppression of the slave-trade that have been made by this country with other states since the general peace:—

In 1814, with France, by Additional Articles to the Definitive Treaty of Peace signed at Paris 30th May (engaging that the slave-trade should be abolished by the French government in the course of five years); and with the Netherlands, by treaty of London, 13th August. Its abolition had also been stipulated in the Treaty of Kiel, concluded with Denmark on the 14th of January.

In 1815, with France, by Additional Article to Definitive Treaty signed at Paris 20th November (by which the two powers, having each already, in their respective dominions, prohibited, without restriction, their colonies and subjects from taking any part whatever in the slave-trade, engage to renew their efforts, through their ministers at the courts of London and Paris, for its entire and definitive abolition); and with Portugal, by Treaty signed at Vienna 22nd January (referring to Treaty of Alliance concluded at Rio de Janeiro 19th February, 1810, in which the Prince Regent of Portugal had declared his determination to adopt the most efficacious means for bringing about a gradual abolition of the slave-trade; and making it now unlawful for any of the subjects of the crown of Portugal to purchase slaves, or to carry on the slave-trade, on any part of the coast of Africa to the northward of the equator).

In 1817, with Portugal, by Convention signed at London 28th July (prohibiting universally the carrying on of the slave-trade by Portuguese vessels bound for any port not in the dominions of his Most Faithful Majesty; and restricting it in other circumstances); with Portugal, by Separate Article, signed at London 11th September (referring to arrangements to be adopted "as soon as the total abolition of the slave-trade, for the subjects of the crown of Portugal, shall have taken place"); with Spain, by Treaty signed at Madrid 23rd September (by which his Catholic Majesty engages that the slave-trade shall be abolished throughout the entire dominions of Spain on the 30th of May, 1820, and that in the mean time it shall not be lawful for any of the subjects of the crown of Spain to purchase slaves, or to carry on the slave-trade, on any part of the coast of Africa to the north of the equator, or in vessels bound for any port not in the dominions of his Catholic Majesty; and by which the restrictions under which the trade may be carried on in other circumstances are specified); and with Radama, king of Madagascar and its dependencies, by Treaty signed at Tamatave 23rd October.

In 1818, with the Netherlands, by Treaty signed at the Hague 4th May (specifying restrictions under which the reciprocal right of visitation and search is to be exercised).

In 1820, with Madagascar, by Additional Articles signed at Tananarivoux 11th October.

In 1822, with the Imaum of Muscat, by Treaty signed at Muscat 10th September; with Netherlands, by Explanatory and Additional Articles, signed at Brussels 31st December; and with Spain, by Explanatory Article signed at Madrid 10th December.

In 1823, with Netherlands, by Additional Article signed at Brussels 25th January; with Portugal, by Additional Articles signed at Lisbon 15th March; and with Madagascar, by Additional Articles signed at Tamatave 31st May.

In 1824, with Sweden, by Treaty of Stockholm, 6th November (arranging reciprocal right of visitation by the ships of war of the two countries).

In 1826, with Brazil, by Treaty of Rio de Janeiro, 23rd November (renewing, on the separation of that empire from Portugal, the stipulations of the treaties subsisting with the latter power).

In 1831, with France, by Convention of Paris, 30th November (stipulating mutual right of search, within certain seas, by a number of ships of war to be fixed every year for each nation by special agreement).

In 1833, with France, by Supplementary Convention of Paris, 22nd March (further regulating the right of visitation by duly authorised cruisers).

In 1834, with Denmark, by Treaty of Copenhagen, 26th July (containing the accession of his Danish Majesty to the Conventions between Great Britain and France of 1831 and 1833); with Sardinia, by Treaty of Turin, 8th August (containing accession of that power to same conventions); and with Sardinia, by Additional Article, signed at Turin, 8th December (respecting place of landing of negroes found in vessels with Sardinian flag).

In 1835, with Spain, by Treaty of Madrid, 28th June (abolishing slave-trade on part of Spain henceforward, totally and finally, in all parts of the world; and regulating a reciprocal right of search); and with Sweden, by Additional Article to Treaty of 1824, signed at Stockholm 15th June.

In 1837, with Tuscany, by Convention signed at Florence 24th November (containing accession of the Grand Duke of Tuscany to French Conventions of 1831 and 1833); with Hanse Towns, by Convention signed at Hamburg 9th June (to same effect); and with Netherlands, by Additional Article to Treaty of 1818, signed at the Hague 7th February.

In 1838, with the Kingdom of the Two Sicilies, by Convention signed at Naples 14th February (containing accession of his Sicilian Majesty to French Conventions of 1831 and 1833).

In 1839, with Republic of Venezuela, by Treaty signed at Caracas 15th March (abolishing for ever the traffic in slaves, so far as it consists in the conveyance of negroes from Africa; expressing the determination of Venezuela to preserve in force the provisions of a law passed in February, 1825, declaring Venezuelans found engaged in that trade to be pirates and punishable with death, and regulating a mutual right of visitation); with Chile, by Treaty signed at Santiago 19th January; with Uruguay, by Treaty signed at Montevideo 13th July; with Argentine Confederation, by Treaty signed at Buenos Ayres 24th May; and with Hayti, by Convention signed at Port-au-Prince 23rd December.

In 1840, with Bolivia, by Treaty signed at Sucre 25th September; and with Texas, by Treaty signed at London 16th November.

In 1841, with France, by Treaty signed at Paris 20th December, which however the French government afterwards refused to ratify; with Mexico, by Treaty signed at Mexico 24th February; and with Austria, Prussia, and Russia, by Treaty signed at London 20th December.

In 1842, with the United States of North America, by Treaty signed at Washington 9th August (stipulating that each party shall maintain on the coast of Africa a naval force, carrying in all not less than eighty guns, "to enforce, separately and respectively, the laws, rights, and obligations of each of the two countries for the suppression of the slave-trade; the said squadrons to be independent of each other," but "to act in concert and co-operation, upon mutual consultation, as exigencies may arise"); with the Argentine Republic; and with the Republic of Hayti.

In 1842, the Ashburton Treaty with the United States of America, by which it was stipulated that each party was to maintain a separate squadron on the coast of Africa to suppress the slave-trade, but if the vessel seized on suspicion was under American colours she was to be delivered to an American cruiser, and if under any other to be given up to the British, to be decided upon as to the fact of slave trading being established, by the courts of the respective countries. [SEARCH, RIGHT OF.] This divided action has not been found effective. With Portugal, by Treaty signed at Lisbon 3rd July.

In 1845, with Brazil; and with France, by a Convention signed at London on the 29th of May (by which each power is to keep up an equal naval force on the western coast of Africa, and the right of visitation is to be exercised only by cruisers of the nation whose flag is carried by the suspected vessel).

The History of the Abolition is to be found in the work under that title by T. Clarkson, and the state of the law, as well as the treatment of slaves practically in the colonies, is most fully treated of in a work on that subject by Mr. Stephen. The writings of the late Sir John Jeremie also contain much useful information on the condition of slavery in the British colonies just before the Emancipation Act. T. Clarkson's other works on the nature of the traffic, which first exposed it to the people of this country, were published in 1787.

The slave-trade was suppressed, but slavery continued to exist in the British colonies. In 1834 the British parliament passed an act by which slavery was abolished in all British colonies, and twenty millions sterling were voted as compensation money to the owners. This act (3 & 4 Wm. IV. c. 73) stands prominent in the history of our age. No other nation has imitated the example. The emancipated negroes in the British colonies were put on the footing of apprenticed labourers. By a subsequent act (1 Vic. c. 19) all apprenticeships were to cease after the 1st of August, 1840, but the day was anticipated in all the West Indian colonies by acts of the colonial legislatures. Slavery exists in the Spanish and Portuguese colonies, and in the southern states of the North American Union. The new republics of Spanish America, generally speaking, emancipated their slaves at the time of the revolution. As the slave population in general does not maintain its numbers by natural increase, and as plantations in America are extended, there is a demand for a fresh annual importation of slaves from Africa, which are taken to Cuba, Puerto Rico, and Monte Video. Since the slave-trade has been declared to be illegal, the sufferings of the slaves on their passage across the Atlantic have been greatly increased, owing to its being necessary for masters of slave-traders to conceal their cargoes by cooping up the negroes in a small compass, and to avoid the British cruisers; they are often thrown overboard in a chase. There is a considerable loss of life incident to the seizing of slaves by force in the hunting excursions after negroes, and in the wars between the chieftains of the interior for the purpose of making captives. There is a loss on their march to the sea-coast; the loss in the middle passage is reckoned on an average at one-fourth of the cargo; and, besides this, there is a further loss, after landing, in what is called the "seasoning" of the slaves. The Portuguese flag has been openly used, with the connivance of the authorities, for carrying on the slave-trade. The Spanish flag has also been used, though with caution, owing to the treaty between England and Spain which formally abolishes the slave-trade on the part of Spain. A mixed commission court of Spaniards and British exists at Havana to try slavers; but pretexts are never wanting to elude the provisions of the treaty. There seems indeed to be a great difficulty in obtaining the sincere co-operation of all Christian powers to put down the slave-trade effectually, although it is certain that in all but the Portuguese and Spanish settlements the traffic has now almost entirely ceased.

Besides the slave-trade on the Atlantic, there is another periodical exportation of slaves by caravans from Soudan to the Barbary states and Egypt, the annual number of which is variously estimated at between twenty and thirty thousand. There is also a trade carried on by the subjects of the Imaum of Muscat, who export slaves in Arab vessels from Zanzibar and other ports of the eastern coast of Africa, to Arabia, Persia, India, Java, and other places. The Portuguese also export slaves from their settlements on the Mozambique coast, to Goa, Diu, and their other Indian possessions.

By a law of the Koran, which, however, is not always observed in all Mohammedan countries, no Mussulman is allowed to enslave one of his own faith. The Moslem negro kingdoms of Soudan supply the slave-trade at the expense of their pagan subjects or neighbours, whom they sell to the Moorish traders. Mohammedan powers will probably never suppress this trade of their own accord.

There is a considerable internal slave-trade in the United States of North America. Negroes are bred and sold in Maryland and Virginia, and some other of the slave-holding states, and carried to the more fertile lands of Alabama, Louisiana, and other southern states. But the attempts of the south, for some time successful, to legalise the recapturing of their escaped slaves in the non-slaveholding states, has at length led to a reaction. On the other hand the election of a president opposed to the views of the slave states, has served as a pretext for the southern states to secede from the Union, and form a new confederacy based on the fullest recognition of slavery as an institution. The issue is however still pending, it being as yet uncertain whether either party will make concessions, or whether or not coercive measures will be employed.

It is maintained by some that the African slave-trade cannot be effectually put down by force, and that the only chance of its ultimate suppression is by civilising central Africa, by encouraging agricultural industry and legitimate branches of commerce, and at the same time spreading education and Christianity; and also by giving the protection of the British flag to those negroes who would avail themselves of it. It is certain that if other countries will not exert themselves, the abolition must be postponed to this remote period. The Africans sell men because they have no other means of procuring European commodities, and there seems no doubt that one result of the slave-trade is to keep central Africa in a state of barbarism. Great hopes are entertained, and a prospect has been afforded, that the influence of commerce will tend to lessen the hateful trade. From the western coast of Africa a large amount of palm-oil is now exported, and as the cultivation of the plant, and the production of the oil, will render the profit of the labour more productive to the rulers than the sale of the labourer, it may induce them to discontinue the practice of undertaking wars for the purpose of procuring captives for sale. It is also hoped by many that cotton may be successfully raised in Africa.

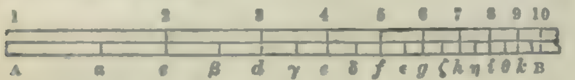
The amount of the slave population now existing in America is not easily ascertained. In Brazil it is estimated there are 2,000,000 negroes, of whom three-fourths are slaves. The slaves in Cuba, according to the census of 1840, numbered 425,521. In the United States the number of slaves was 3,204,313 by the census of 1850, which is 716,989 more than the number according to the census of 1840; yet ten states which returned slaves in 1840 returned none in 1850, the holding of them having wholly (or virtually) ceased.

Societies for the ultimate and universal abolition of slavery exist in England, France, and the United States, and they publish their reports; and a congress was held in London, in June, 1840, of delegates from many countries to confer upon the means of effecting it. The American Society has formed a colony called Liberia, near Cape Mesurado, on the west coast of Africa, where negroes who have obtained their freedom in the United States are sent, if they are willing to go [LIBERIA, in GEOG. DIV.] The English government has a colony for a similar purpose at Sierra Leone, where negroes who have been seized on board slavers by English cruisers are settled. [SIERRA LEONE, in GEOG. DIV.] Several thousands of negroes who have escaped from slavery in the United States are now settled in Canada, earning a livelihood by their own industry.

SLEEP; SLEEP-WALKING. [SOMNAMBULISM.]

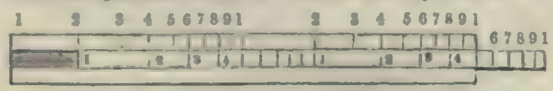
SLIDE (or SLIDING) RULE. The sliding-rule is an instrument for the mechanical performance of addition and subtraction, which is converted into an instrument for the mechanical performance of multiplication and division by the use of logarithmic scales, instead of scales of equal parts.

This instrument has been greatly undervalued in our country, in which it was invented, and is very little known on the Continent; for though a French work on the subject, published in 1825, which is followed by the writer of a more recent mathematical dictionary in the same language, assures us that in England the sliding rule is taught at schools at the same time with the letters of the alphabet, we believe it would be more correct to say that nine Englishmen out of ten would not know what the instrument was for if they saw it, and that of those who even know what it is for, not one in a hundred would be able to work a simple question by means of it. For a few shillings most persons might put into their pockets some hundred times as much power of calculation as they have in their heads: and the use of the instrument is attainable without any knowledge of the properties of logarithms, on which its principle depends.

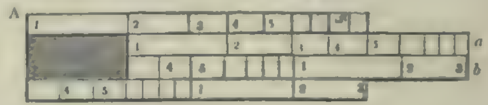


We have before us a logarithmic scale, of which A B, called the *radius*, may stand for the logarithm of 10, 100, 1000, &c.: but if A B should be, say the logarithm of 100, then A *c* is that of 20, A *d* of 30, and so on. If this scale be repeated several times, beginning again at B, and if it be also large enough to be subdivided to a greater extent than can be shown in the diagram, any multiplication can be approximately performed by addition, and any division by subtraction; which may be done with a pair of compasses. That is to say, the figures of the product may be found, exactly or approximately, and the meaning of the figures must be settled from the known character of the result. For example, to find 4 times 15:—First, let A B mean the logarithm of 100, then A *a* is that of 15; next let A B mean the logarithm of 10, then A *e* is that of 4. Take A *a* on the compasses, and set it on to the right of *e*; it will be found that the point *g* is attained, directly under 6. But 4 times 15 must be tens; therefore 60 is meant, or 4 × 15 = 60. Next to divide 90 by 45: from A *k* take A δ, or set off A δ from *k* towards the left. The point *c* will be attained, under 2, which is the quotient. Next to find 7 times 5: set off A *f* from *h* towards the right, and the point γ of the scale following B will be attained, and 35 is the answer. But had it been to multiply 7 by ·5 or 5-tenths, this 35 would have meant 3·5 or 3½. Attempts are made in works professing to explain the sliding-rule to give rules for the determination of the character of the figures in the answer, but without any success. It is all very well for a few chosen examples, but an attempt to do without the book soon shows the insufficiency of rules. If, on a large scale, 653 should be the figures of an answer, common sense, applied to the problem, must say whether it is ·0653, ·653, 6·53, 65·3, 653, 6530, 65300, &c. which is meant. A knowledge of decimal fractions is therefore indispensable.

Now these additions and subtractions might be performed by a pair of rulers made to slide each along the other; but whether they are kept together by the hand, or whether the one ruler slides in a groove along the edge of the other, matters nothing to the explanation. The following diagram represents the two rulers in one relative position. Here 1 on the slide is made to match 2 on the fixed ruler, and the instrument is now in a position to multiply by 2, to perform every division in which the quotient is 2, and to work every question in the rule of three in which the ratio of the first term to either the second or third is that of 2 to 1, or of 1 to 2. And here let us observe, that much the best way of beginning to use the sliding-rule is not by working given questions, but by setting the slide at hazard, and learning to read the questions which are thus fortuitously worked.

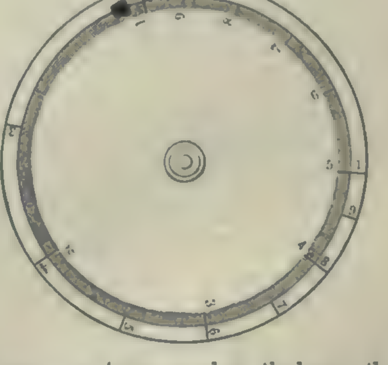


In the cut before us we have the 1 of the slide placed at 2 of the fixed ruler; consequently 6 on the slide comes under what would be 12 of the fixed ruler if the secondary graduations were inserted. Again, 4 comes over 2, and 9 over 45, giving 4 : 2 :: 9 : 4·5, the decimal point being inserted by intuition. To show the sort of results which we obtain from such a slide of 5½-inches radius (or from 1 to 1), we take one of this sort, and throw 1 of the slide at hazard between 225 and 230 on the fixed ruler, a little farther to the right than it is on the preceding diagram; guessing at the interval, it seems 228·5. We detect it more exactly by looking at 5 on the slide, which is hardly visible in advance of 114 on the scale. As far then as the divisions, aided by our judgment of this interval, inform us, we have 114÷5 = 22·85, the truth being 22·8. Again, we find 628 (fixed) just over 275 (slide), the 8 being estimated; hence, by the scales we learn that 628÷275 = 2·285; the truth being 2·2836. Thirdly, we estimate that 1725 (fixed) falls over 757 (slide), and that 276 (fixed) falls over 121 (slide). That is, the ruler informs us that 1725 : 757 :: 276 : 121; the fourth term should be 121·12, as found by computation. We take a larger scale, having 7½ inches of radius, and setting 1 on the slide to 228·5, we find 1725 appears to fall over what we should judge to be 756 rather than 757. Now 1725÷757 = 2·2787, and 1725÷756 = 2·2818. Both give on the scales 2·285, so that the advantage is slightly in favour of the larger scale, but not so much as we should have expected. We now try one of 24 inches radius, and setting 1 on the slide to 2·285 on the fixed ruler, we find that 1725 (fixed) falls over 754·7 (slide), the last 7 being estimation. Now 1725÷754·7 = 2·2857, which gives the advantage again (but not so decidedly as might have been expected) to the large rule. The fact is, that it is rather ease than proportionate accuracy which is gained by the large rules: the preceding results required care and close attention on the 5½ inch rule; were obtained with moderate care on the 7½-inch; and taken off instantly from the 24-inch rule. Moreover, divisions on wood, made in the usual way, do not allow accuracy to increase with the size: if these rulers were divided on brass, and with the precautions taken in astronomical instruments, it would be a very different thing; but after all, the wonder is that the common wooden rules should be so accurate as they are.



The next step in the description is as follows:—It matters nothing whether the second scale be really made consecutive with the first, or occupy any other part of space: provided that when 1 and 1 are brought together on the first scale, 1 and 1 also come together on the second, and that the first slide and its continuations slide equally. We see this in the diagram before us: *a b* is one slide, and A B are two rulers on opposite sides of the groove. When *a b* is pushed home, A and *a* present coinciding scales, as do B and *b*: we should rather say, that the last is not one scale, but the end of one and the beginning of another; the 1 of B and *b* being in the middle. The consequence is, that so long as 1 of the scale *b* is not pushed out so far as to fall out of the groove (which is never necessary, since there is a whole scale on B), there is always the power of reading every result of the multiplication in hand. In the diagram, 1 on *b* is pushed out to 2 on B, and on the upper scales (A and *a*) we see 2 × 2 = 4, 2 × 3 = 6, 2 × 4 = 8, 2 × 5 = 10; on the lower (B and *b*), 2 × 4 = 8, 2 × 5 = 10, 2 × 6 = 12, 2 × 7 = 14, 2 × 8 = 16, 2 × 9 = 18, 2 × 10 = 20. This modification was invented by Mr. Silvanus Bevan (Nicholson's 'Journal,' vol. xlix., p. 187); but thirty years before this Mr. Nicholson ('Phil. Trans.', 1787, p. 246) had pointed out how to divide the whole radius into four parts, two on each face.

A simple plan, and in some respects the best, is to make a revolving circle turn upon a fixed one, in which case the scale is its own continuation, as in the following diagram. The two circles have a common pivot, and the upper one turns round on the lower; the rim of the inner circle being bevelled down to the plane of the lower. A complete logarithmic scale is marked on each circumference, and it will readily be seen that the scales are placed so as to point out multiplications by 2, as in the former instances, and also that the recommencement of the scale begins its continuation. Instead of two circles there might be two thin cylinders, turning on a common axis, the graduations being made on the rim. Thirty years ago, an instrument-maker at Paris laid down logarithmic scales on the rims of the box and lid of a common circular snuff-box: one of two inches diameter would be as good an aid to calculation as the common engineer's rule. But either calculators disliked snuff, or snuff-takers calculation, for the scheme was not found to answer, and the apparatus was broken up.



The form first proposed by Oughtred (presently to be mentioned) was a modification of the preceding. Instead of two circles, two pointing radii were attached to the centre of one circle, on which a number of concentric circles were drawn, each charged with a logarithmic scale. These pointers would either move round together, united by friction, or open and shut by the application of pressure: they were in fact a pair of compasses, laid flat on the circle, with their pivot at its centre. Calling these pointers antecedent and consequent, to multiply A and B the consequent arm must be brought to point to 1, and the antecedent arm then made to point to A. If the pointers be then moved together until the consequent arm points to B, the antecedent arm will point to the product of A and B.

It will be observed that in every construction the logarithmic spaces are very unequal, those near the end of the scale being small when compared with those at the beginning. This is not so great a disadvantage as might be supposed, for it makes the liability to error increase in nearly the same proportion with the result, so that the *per centage* of error in the sliding-rule is nearly the same thing in all its parts. For example, the scale going from 10 to 100, the interval from 10 to 11 is to that from 99 to 100 as 207 to 22, nearly in the proportion of 10 to 1. The tendency to absolute error will be inversely as these intervals, or nearly in the proportion of 1 to 10: the tendency to error is therefore about 10 times as great precisely when the result estimated becomes ten times as great. Oughtred appropriated two circles to his logarithms of sines, and it would be easy in his construction of the 'circles of proportion,' as he called them, to distribute the scale among different circles in such a manner that the graduations should be nearly equal throughout. But the mathematician will easily see that that the most perfect mode of developing this idea would be to lay down the scale on a revolution of a logarithmic spiral, having the pointers joined at its pole. The graduations would then be absolutely at equal distances from each other on the arc of the spiral.

Another modification of the principle of the sliding-rule is as follows:—Let the divisions be all made equal, and the numbers written upon the divisions in geometrical proportion. If this were done to a sufficient extent, any number might be found exactly or nearly enough upon the scale; the only difficulty being that very small divisions do not give room enough to write the numbers. This modification of the principle has been applied in two very useful modes by Mr. MacFarlane. In the first, two cylinders moving on the same axis, on one side and the other of a third, give the means of instantaneously proposing and solving any one out of several millions of arithmetical questions for the use of schools and teachers. In the second, one circle revolving upon another gives the interest upon any sum, for any number of days, at any rate of interest under 10 per cent.

The rules for using the sliding-rule, in its most simple form, may be symbolically expressed in the following manner:—

$$\begin{array}{cc|cc|cc|} 1 & B & A & B & A & C \\ A & AB & 1 & B \div A & B & C \times B \div A \end{array}$$

Thus, if 1 on either ruler be brought opposite to A on the other, B on the first ruler is brought opposite to A B on the other. But if the slide be taken out and inverted, we have the following rules:—

$$\begin{array}{cc|cc|cc|} 1 & B & A & B & A & C \\ A & A \div B & 1 & A \div B & B & A \times B \div C \end{array}$$

We now proceed to some of the additions which are frequently made to sliding-rules, premising that we do not describe any one in particular, but refer for detail to the tracts which are afterwards cited. For the extraction of square or cube roots, or the formation of squares or cubes, the following method is adopted:—In the case of squares and square roots, for instance, there is a pair of scales, one on the slide and one on the fixed ruler, of different radii, the radius of one being twice as long as that on the other: for cubes and cube roots the radius of one is three times as long as the other. On the former scale (that of squares and square roots) the rules are now as follows:—

$$\begin{array}{lccc|ccc|} \text{Longer Rad.} & 1 & A & \sqrt{A} & 1 & B & (\sqrt{B}):A \\ \text{Shorter Rad.} & 1 & AA & A & A & AB^2 & B \\ & A & B & A\sqrt{B} & A & C & A\sqrt{(C:B)} \\ & 1 & B^2\cdot A^2 & B & B & BC^2:A^2 & C \end{array}$$

The denomination of the answer, or the place of the decimal point, must be determined by independent consideration, as before; but there is one circumstance to be attended to in every case in which two of the data are to be read on the shorter scale. For example,* suppose it is required to estimate $\sqrt{(2:7)}$. By the second formula, 7 on the shorter scale is placed opposite to 1 on the longer, and 2 on the shorter scale is then opposite to 1693 on the longer. The answer from the scale is then ·1693, to all appearance; but this is not $\sqrt{(2:7)}$, but $\sqrt{(2:70)}$. The place on the longer scale which should give the answer has no slide opposite to it, but only empty groove. But mark where 1 on the shorter scale is opposite to a part of the longer (between 119 and 120), and push the slide in from left to right till the first 1 on the shorter scale comes where the second now is; then look under the second 2 of the shorter scale, we have 534; and ·534 is the true answer so far as the scale will give it. We have taken the most straightforward plan of reading the rule, and have not space for all the details which are in works on the subject, particularly the method of using the slide of numbers with a scale of numbers above and of square roots below. The following is the general principle applicable to the preceding case:—

It is well known that, whereas in common division the place of the decimal point has nothing to do with the significant figures of the quotient, yet in extracting the square, cube, &c., roots, the figures of the root are altered by a change of the decimal point, unless it be changed by an even number of places in extracting the square root, by three or a multiple of three places in the cube root, and so on. In extracting the square root, a number may either have two figures in its first period, or one; thus ·07616 and ·7616 must (in the rule for extraction) be pointed

$${\cdot}0\dot{7}6\dot{1}6\dot{0} \quad \text{and} \quad {\cdot}7\dot{6}1\dot{6}.$$

Let us call numbers *unidigital* or *bidigital*, according as there are one or two significant figures in the first period. Then the application to the sliding-rule is, that on the shorter scale numbers of the same name must be read either on the same radius or with a whole radius intervening, while numbers of different names must be read on different radii. In the scale for the extraction of the cube root, numbers must be distinguished into unidigital, bidigital, and tridigital; and signifying these by their initial letters, and taking the succession U B T U B T, &c., there must be the same relation between the scales on which they are read that there is between the places of their letters in the preceding list. Thus, if U be read on one radius, T must either be read on that immediately preceding, or on the next but one. Thus, in the preceding question, which we first solved wrongly, we have 2 and 7 to consider on the shorter scale, the pointing of which is—

$$\dot{2}{\cdot}0\dot{0}0\dot{0} \quad \text{and} \quad \dot{7}{\cdot}0\dot{0}0\dot{0},$$

and both are unidigital numbers. Bringing 7 on the shorter scale to 1 on the longer, we see that the next 2 is on a different radius; it would do then for 70, or ·7, or ·007, but not for 7. By the process we followed we took not indeed a 2 on the same radius with our 7, but on the next radius but one, and thus obtained the correct answer. These points, and others (such as the meanings of the lines of sines, tangents, &c., annuities, &c., which are found on several rules) can only be mastered by those who are acquainted theoretically with logarithms, trigonometry, &c.; for after all the sliding-rule will not teach the method of working any question, but will only afford aid in computation—in common multiplication and division, to any one; in higher rules, to those who understand their principles. Oughtred, the inventor, kept the instrument by him many years, out of a settled contempt for those who would apply it without knowledge, having "onely the superficiall scumme and froth of instrumentall trickes and practises;" and wishing to encourage "the way of rationall scientiallists, not of ground-creeping Methodicks." A little distinction between that portion of its use which is generally attainable, and that which requires mathematical knowledge, would have been more reasonable.

On the carpenter's and engineer's sliding-rule are engraved a number of numerals in columns with headings, of which the following is a specimen:—

	SQUARE.			CYLINDER.		GLOBE.	
	FFF	FII	III	FI	II	F	I
CAST IRON	·0022	·323	3·878	·411	4·935	·0043	7·406

These divisors (called gauge-points) are intended to convert into pounds the weight of a rectangular prism, cylinder, or globe, of cast-iron; the first, on three suppositions, namely, all dimensions in feet, one in feet and two in inches, and all in inches; the second, on the suppositions that the length is in feet and the diameter in inches, and that both are in inches; the third, on the supposition that the diameter is either in feet or in inches. We shall here content ourselves with verifying one of these, say the first of those marked "cylinder," which will show the nature of the divisor.

The specific gravity of cast-iron is 7·207, and the content of a cylinder of D *inches* diameter and L *feet* of length is $·7854 \times D^2 L$ divided by 144, in cubic feet. A cubic foot of water weighs 62·321 pounds avoirdupois: one of cast-iron, therefore, weighs $62·321 \times 7·207$; whence the weight of the cylinder is, in pounds,

$$62{\cdot}321 \times 7{\cdot}207 \times {\cdot}7854\, D^2L \div 144, \text{ or } \frac{D^2L}{G};$$

$$\text{where } G = \frac{144}{62{\cdot}321 \times 7{\cdot}207 \times {\cdot}7854}, \text{ or } {\cdot}4082;$$

near enough to ·411 to illustrate our object, but showing that the computer of this divisor used a specific gravity slightly differing from the above. The rule in all the cases is to multiply the three dimensions together, diameters or lengths, and to divide by the divisor given in the table. The term gauge-point, which properly belongs to the part of the scale on which the divisor is marked, has passed to the divisor itself.

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* The reader will not understand this, unless with the scale in his hand. The common carpenter's rule or Bevan's rule will do, in which two consecutive radii are on the shorter scale, and one radius of twice the length on the longer.

The following list of sliding-rules contains all, or nearly all, which can be useful to any one :—

1. Common Engineer's Rule, or Carpenter's Rule in its best form. A double 12-inch rule, a slide of two radii with the same scale on one side, and a scale of one radius of double length on the other, with divisors. (Sold by all rule makers.) There is a description in Kentish's 'Treatise on a Box of Instruments,' &c., London, 1839.

2. Bevan's Engineer's Rule, 12 inches. Has slides on both faces (which may be exchanged), and serves for squares, cubes, square roots of cubes, &c. There are scales on the backs of the slides and in the grooves, for sines, tangents, inverted numbers, compound interest and annuities at 5 per cent. (Cary, Strand, with an explanatory treatise.)

3. Henderson's Double-Slide Rule, 12 inches. Has two parallel contiguous slides, with scales of numbers fixed above and below, and solves at one operation most sets of multiplications and divisions not exceeding five operations. At the back are tables of divisors for solids.

4. Woollgar's Pocket Calculator, 8 inches. The two slides work in either of the grooves : the backs and the grooves have scales of sines, tangents, areas of polygons, circular segments ; interest, annuities, certain and for lives, at several rates of interest. An addition may be made by a metal slip, giving the solution of the same questions as the last rule.

5. Woollgar's Pocket-Book Rule, 6 and 8 inches. Two radii, one under the other, as described in the preceding part [*] of the article ; a line for sines and duplicate proportions at the back of the slide. At the bottom of the groove are sometimes inserted lines for finding the relations of right-angled triangles, for cask-gauging, and for cuttings and embankments.

6. Excise Officer's Sliding Rule, modern form. Sold at the Excise Store-office, and by some of the instrument-makers. The old Excise rule was a thick block, with a slide on each face.

7. Bayley's Rule, (Elliot, Strand) has a scale of numbers, squares, and cubes, and a scale of equal parts, of the length of the line of squares, from which the logarithm of a number can be approximately read. This line is of considerable use in operations connected with higher powers : it is found also in Bevan's rules. The constructor of this scale, which is well divided and convenient, has a full treatise on the whole subject in the press.

Among separate treatises not yet noted are Flower's, 8vo., London, 1768 ; Mackay's, 8vo., 2nd edit., London, 1811 ; do. Leith, 1812 ; 'Instruction sur la Manière de se servir de la Regle à Calcul.,' petit-in-8vo., Paris et Dijon, 1825 ; 'The Universal Ready-Reckoner,' by an Idle Gentleman, 12mo., London, 1839 ; and there is a good deal on the subject in Ingram's 'Concise System of Mathematics,' 12mo., Edinburgh ; and Bateman's 'Excise Officer's Manual,' 12mo., London.

Between the sliding-rule and the book of logarithms comes the card of four-figure logarithms, published by Messrs. Taylor and Walton (explained in the 'Companion to the Almanac' for 1841), to which has been added a similar card for sines and tangents. A sliding-rule, which would *in all parts* compete with these tables in accuracy must have a radius of from 8 to 10 feet, and would be unmanageable. At what length the card begins to be more easily used than the rule we cannot determine, but we should suspect that the former would be preferable to a rule of four feet radius. We have found the rule of 24 inches extremely useful in checking the material figures of more minute calculations, particularly when there are many divisions by the same divisor.

The history of the sliding-rule, had it ever been properly given, would be matter for a few lines of our work, in the way of abbreviation and reference. As it is, we have not only to establish the main points, but also to point out a specimen of the manner in which the account of early English science has been written. Harris's 'Lexicon Technicum' (1716) informs us that sliding-rules 'are very ingeniously contrived and applied by Gunter, Partridge, Cogshall, Everard, Hunt, and others, who have written particular treatises about their use and application.' Stone's 'Mathematical Dictionary' (1743) has the same words. Dr. Hutton ('Math. Dict., 1815) informs us that they are variously (not ingeniously) contrived and applied by different authors, particularly Gunter, Partridge, Hunt, Everard, and Coggleshall. Other writers repeat this sentence in their own ways, and the summing up is this :—the recognised history of the sliding-rule consists in the names of five persons ; all our best English authorities are unanimous in stating that these men 'contrived and applied' sliding-rules, either ingeniously or variously ; but to the credit of this century be it spoken, that it was our historian who altered the chronological order, and spelt Coggleshall's name right : had it not been for the research of Dr. Hutton, it might have been Cogshall to this day.

We now go on to something more like history. It is generally stated that Gunter invented the sliding-rule. This is not correct ; Gunter neither invented this rule nor wrote about it ; and though he was the first (*On the Crosse-staffe*, book i., cap. 6) who used a logarithmic scale, it was in the manner described at the beginning of this article, compasses being used to make the additions and subtractions. Gunter's rule is used up to the present time, under that name, in the navy, without any slides.

The real inventor of the slide was OUGHTRED [BIOG. DIV.], who was also the first writer upon it. He was a man who set but little value upon instrumental aids, unless in the hands of those who had previously learned sound principles, which (as we have seen) he himself testifies. In the year 1630 he showed it to his pupil William Forster, who obtained his consent to translate and publish his own description of the instrument, and rules for using it. This was done under the following title : 'The Circles of Proportion and the Horizontal Instrument,' London, 1632 ; followed, in 1633, by an 'Addition, &c.,' with an appendix, having title, 'The Declaration of the two Rulers for Calculation.' The following extract from W. Forster's [*] dedication to Sir Kenelm Digby will explain the whole :—

"Being in the the time of the long vacation 1630, in the Country, at the house of the Reverend, and my most worthy friend, and Teacher, Mr. William Oughtred (to whose instruction I owe both my initiation, and whole progresse in these Sciences), I upon occasion of speech told him of a Ruler of Numbers, Sines, and Tangents, which one had bespoken to be made (such as is usually called Mr. Gunter's Ruler), 6 feet long, to be used with a payre of beame compasses. He answered that was a poore invention, and the performance very troublesome : But, said he, seeing you are taken with such mechanicall wayes of Instruments, I will show you what devises I have had by mee these many yeares. And first, hee brought to mee two Rulers of that sort, to be used by applying one to the other, without any compasses : and after that he shewed mee those lines cast into a circle or Ring, with another moveable circle upon it. I seeing the great expeditenesse of both those wayes, but especially of the latter, wherein it farre excelleth any other Instrument which hath bin knowne ; told him, I wondered that he could so many yeares conceale such usefull inventions, not onely from the world, but from my selfe, to whom in other parts and mysteries of Art he had bin so liberall. He answered, That the true way of Art [†] is not by Instruments, but by Demonstration : and that it is a preposterous course of vulgar Teachers, to begin with Instruments, and not with the Sciences, and so instead of Artists, to make their Schollers only doers of tricks, and as it were Juglers : to the despite of Art, losse of precious time, and betraying of willing and industrious wits unto ignorance, and idlenesse. That the use of Instruments is indeed excellent if a man be an Artist : but contemptible, being set and opposed to Art. And lastly, that he meant to commend to me the skill of Instruments, but first he would have me well instructed in the Sciences. He also shewed me many notes, and Rules for the use of those circles, and of his Horizontall Instrument (which he had projected about 30 yeares before) the most part written in Latine. All which I obtained of him leave to translate into English, and make publique, for the use and benefit of such as were studious, and lovers of these excellent Sciences."

Oughtred gave his right in the invention (so soon as it was settled to be published) to Elias Allen, a well-known instrument-maker, near St. Clement's Church, in the Strand. In walking to and fro from his shop, he communicated his invention to one Richard Delamain, a mathematical teacher whom he used to assist in his studies. This Delamain not only tried to appropriate the invention to himself, but wrote a pamphlet of no small scurrility against Oughtred, which the latter answered in an 'Apologeticall Epistle' fully as vituperative ; which epistle was printed at the end of W. Forster's translation. It contains some quantity of biographical allusion, and must not be forgotten by a mathematical historian of the times. W. Forster's work was republished in 1660, by A. H. (Arthur Haughton, another pupil of Oughtred), with Oughtred's consent, but the dedication and epistle were omitted.

The next writer whom we can find is Seth Partridge, in a 'Description, &c. of the Double Scale of Proportion,' London, 1685. He studiously conceals Oughtred's name : the rulers of the latter were separate, and made to keep together in sliding by the hand ; perhaps Partridge considered the invention his own, in right of one ruler sliding between two others kept together by bits of brass. Coggleshall's ruler was made in both ways, that is, with the rulers attached and unattached ; it appears to have come in at the end of the 17th century. Since that time several works have been written, and various modifications of the ruler proposed. Ward ('Lives of Gresham Professors') is incorrect in saying that Wingate carried the sliding rule into France in 1624 : it was Gunter's scale which he introduced there. In fact the slide was little used and little known till the end of the century. Leybourn, himself a fancier of instruments, and an improver (as he supposed) of the sector, has 30 folio pages of what he calls instrumental arithmetic in his 'Cursus Mathematicus' (1690), but not one word of any sliding-rule, though he puts fixed lines of squares and cubes against his line of numbers in his version of Gunter's scale.

Finding so meagre an account on this matter in publications professedly mathematical, we did not at first think of having recourse to any others. When we had finished the preceding however, we thought of consulting the 'Biographia Britannica,' and there we found, in the middle of a very full life of Oughtred, the whole account of the invention of the sliding-rule, exactly as above, and from the same authorities. On looking at Dr. Hutton's account in the Dictionary, we perceive that he has either used this memoir or some copy of it; but without giving any information on the subject of the present article.

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[*] The maker of this slide has them of various lengths up to 24 inches.

[*] This man must not be confounded with the Gresham professor of his name ; nothing more than his connection with Oughtred is known of him. The one whose name is so much connected with Gunter is Samuel Foster (died 1652), Gresham professor of astronomy.

[†] Here is the old use of the word art ; we should now say science. [SCIENCE.]

We shall conclude this article by some account of a new species of sliding-rule, invented by Dr. Roget ('Phil. Trans.' for 1815), which would be very useful in the hands of writers on statistics, and would sometimes save much trouble to the mathematician. The slide contains a common logarithmic line of two radii, each 10 inches in length. The fixed ruler has not logarithms, but logarithms of logarithms denoted by its spaces. For instance, reckoning from 10 (remembering that log log 10 = 0), the space from 10 to 100 is log log 100, or log 2, the same space as from 1 to 2 on the slide. And since log log x is positive or negative, according as x is greater or less than 10, we have the *logologarithms* laid down on the left for numbers less than 10, and on the right for numbers greater. This instrument is constructed by Mr. Rooker, and in this manner: 10 is on the middle of the upper ruler, which ends on the right at 10^{10}, or ten thousand millions; and on the left at 1·25. At the extreme right of the lower ruler we find 1·25 again, from which we recede to 1·0025 on the extreme left. The upper and lower rulers are so adjusted that from the end of one to the beginning of the other it is exactly two radii, so that a setting on the upper ruler applies also to the lower, but it may be necessary first to slip the slide a whole radius forwards or backwards, in the manner described in the preceding part of the article. And here again the meaning of the reading on the slide must frequently be determined by common sense applied to the problem.

When 1 on the slide is placed opposite to a on the ruler, we have b on the slide opposite to a^b on the ruler. Or using the preceding rotation—

$$\begin{array}{lll|ll|ll} \text{Rule} & a & a^b & a & \sqrt[b]{a} & a & \sqrt[b]{a^c} \\ \text{Slide} & 1 & b & b & 1 & b & c \end{array}$$

The approximations of this rule are equally easy whether applied to fractional or integer exponents, and Dr. Roget justly observes that it gives a much better idea of the rapid increase of powers than simple reflexion. It is so little known even to mathematicians, that we put down some of its results as specimens of its powers. Set 1 on the slide opposite to 3·14 on the rule, and we find for the approximate powers of this number by simple inspection 9·85, 31, 97, 300, 960, 3000, 9500, 29,500, 93,000, &c. The square root is 1·772, the cube root 1·463, the fourth root 1·331, the fifth root 1·257. We must now change the slide, as above directed, so as to put it in connection with the lower scale, and the proceeding roots are 1·215, 1·178, &c. All questions of increase of money, population, &c., are in this manner reduced to simple inspection, and very easy trial gives that approximate solution of exponential equations which the mathematician must find before he applies his more extensive methods. Thus, to form the table of logarithms in Scale the base of which is $\sqrt[12]{2}$:—Set 12 on the slide opposite to 2 on the ruler, and the table is ready, as far as the instrument will give it. Thus, opposite to 3, 4, 5, &c., we find 19·0, 24, 27·9, 31·0, 33·7, 36·0, &c., almost exactly as in the table cited. It is also worth notice that each division of the upper fixed ruler answers to the hundredth power of the division directly beneath it on the lower fixed ruler. Thus, wishing to know what effect would be produced in 100 years upon a population which increases 3·46 per cent., we set unity to 1·0346 on the lower scale, and find at once 30·025 on the upper ruler, being the number by which the present population must be multiplied.

The late Mr. Woollgar (to whom we were indebted for much information in this article, and who made a particular study of the sliding-rule) carried to a considerable extent the principle of making the slide or the rule (no matter which) bear, not the logarithms of the numbers marked on its graduation, but those of the values of a function of those numbers ('Mechanics' Magazine,' No. 849, vol. xxxii.) Let a slide be so graduated that the interval from a given point to the graduation x represents log ϕx. When x is then ascertained (by the common scale, if necessary), the formula $a\phi x$ is immediately deduced from the common scale and the new slide. Nor need there be a new slide: for any scale being laid down in the groove, the common slide, by having its end made to coincide with one or another division of the scale in the groove, may be rendered capable of answering the purpose of a new slide.

We long since obtained from Paris a circular logarithmic scale in brass, altogether resembling the one figured and described in the preceding part of this article, with the addition only of a clamping screw. This instrument, the scale of which is 4½ inches in diameter, is so well divided that it will stand tests which the wooden rules would not bear without showing the error of the divisions. But here arise disadvantages which we had not contemplated. In the first place, no subdivision can be well made or read by estimation, unless the part of the scale on which it comes is uppermost or undermost, which requires a continual and wearisome turning of the instrument. In the next place, to make the best use of it, and bring out all its power, requires (we should rather say renders worth while) such care in setting and reading, as, unless a microscope and tangent screw were used, makes the employment of the four-figure logarithm card both shorter and less toilsome. For rough purposes, then, a wooden rule is as good; for more exact ones, the card is better. We made a fair trial of both on the tables in Solar System, and are perfectly satisfied that though the French brass arithmometer did, with great care, bring out the results required, the four-figure card did the work more easily. But, had we wished to abandon two or three units in the last places of figures, there would then have been no doubt that the instrument would have been the easier of the two: but then a straight wooden rule of the same radius would have done quite as well, and been more convenient still. ('Mechanics' Magazine,' No. 949.)

SLIDING SCALE. [Slide or Sliding Rule.]

SLING, an instrument with which stones or other missiles may be thrown to a great distance. In its simplest form the sling consists of a thong of leather, or a piece of cord or some woven fabric, both ends of which are held in the hand of the slinger. The stone or missile is placed in the fold or double of the thong, which is made wide at that part, and sometimes furnished with a slit or socket for the purpose of holding it; and the sling is then whirled round to gain an impetus. When a sufficient degree of centrifugal force is thus generated, the slinger allows one end of the thong to escape, and the stone, being thereby released, flies off with considerable velocity. In the hands of an expert slinger, this instrument may be made to project missiles to a great distance, and with surprising accuracy.

The simplicity and portability of the sling, and the facility with which supplies of ammunition for it might be obtained, led to its extensive use among the ancients as a weapon of war, as well as for other purposes. Its common use among the Jews is intimated by several passages of scripture. Several ancient paintings represent the use of the sling at an early period by the Egyptians. Some of these are given by Wilkinson. In the Greek and Roman armies the light troops consisted in great part of slingers, who were called *σφενδονῆται*, or *funditores*, from *σφενδόνη*, and *funda*, the Greek and Latin names of the weapon. The Carduchi, according to Xenophon, annoyed the retreating army of the Ten Thousand by their powerful slings. ('Anab.', iv. 1, &c.) There are no slingers mentioned in Homer; and the word which usually means sling (*σφενδόνη*) occurs only once ('Iliad,' book xiii., line 599), and then not in the sense of sling, but in the primary sense of the word, which means a broad band or bandage. This passage has sometimes been strangely misunderstood. The sling is not mentioned by Herodotus; and it is an error to assign the use of it to the Persians, for which there appears no evidence but a loose expression in Diodorus (xviii. 51), where he speaks of 'Persians, bowmen and slingers, five hundred." The natives of the Balearic Islands attained the highest reputation for their skill in its management; which is attributed to their custom of teaching their children, while very young, to wield it, and forbidding them, it is said, to taste their food until they had dislodged it from a post or beam by means of a sling. Besides stones, leaden plummets, cast in moulds, were used as projectiles for the sling. These, which were called *glandes*, or *μολυβδίδες*, were of an elongated spheroidal form; somewhat resembling that of olives or acorns. They have been often discovered in various parts of Greece, and frequently bear on one side a figure of a thunderbolt, and on the other side either the word ΔΕΞΑΙ (take this), the name of their owner, or some other inscription or device. Some of these were of considerable size, weighing as much as an Attic pound, or 100 drachmæ. Fireballs also have been thrown by slings. Some of the slings used by the ancients were managed by more than one cord; one, two, or three being used, according to the size of the missiles to be thrown.

The sling was long used in England. The Saxons certainly used it, and seem to have been skilful in its management. Besides the ordinary sling, they used one attached to a staff or truncheon three or four feet long, wielded with both hands. This kind of sling, with which large stones were thrown, appears to have been used principally in sieges and in naval warfare. It is represented in an old drawing, supposed to be by Matthew Paris. Slingers formed a part also of the Anglo-Norman soldiery; and the sling had not fallen into disuse as a military weapon at the commencement of the 15th century The use of the sling may now be considered obsolete in this country as an offensive weapon.

(Wilkinson's *Manners and Customs of the Ancient Egyptians*, first series, vol. i.; Strutt's *Sports and Pastimes*.)

SLIP, *Earthwork*. When in an embankment, or cutting, the materials move laterally in consequence of some dynamical action, they are said to slip, and they do so occasionally under circumstances which can only be overcome with great difficulty, and at great expense. Slips occur either when heavy loads are placed on incoherent materials, which under such circumstances are simply displaced; or they occur when the earth is of such a nature as to absorb so much water as to become a semi-fluid mud; or when there are intercallated between more impermeable strata beds of sand, or other open materials susceptible of being removed. The former of these sources of danger can easily be avoided by carrying the foundations of the intended load to such a depth as to ensure their not exerting any detrusive force; the latter sources of danger are far more complicated, and they require to be dealt with very carefully, on account of the numerous considerations attached to the change of state the materials often assume before they get into motion.

Uniformly permeable materials, such as broken stones, gravel, or shingle, are not exposed to slip after they have once taken their angle of repose, because the gravity of the separate stones is sufficient to keep them in their places whilst the water falling upon their exposed surfaces is percolating through them. Very fine sands, however, are able to be rendered semi-fluid under some conditions, and they then have no angle of repose, and are able to spread in every direction. Some clays, such as the Oxford clay, the gault, and the London clay, which seem to have originally been the alluvial muds of marine estuaries, subsequently dried and consolidated, are susceptible of absorbing again quantities of water able to bring them into their original state; and it seems, from the experience of our railway and canal engineers, that many years must pass before cuttings executed in those formations attain permanent conditions of stability. Instances have been known in which slips have taken place in the Oxford clay formation when the slopes have been even 10 to 1 (10 base to 1 in vertical height); and the New Cross cutting of the Brighton Railway, in the London clay, slipped in the winter 1860-61, although it had formed part of the cutting for the old Croydon canal executed nearly sixty years since. Slips, it may be added, occur in undisturbed natural deposits exposed to the action of the sea, or of running water, and the same class of accidents, above described as occurring in the cuttings and embankments executed by the hand of man, occasionally happen in consequence of the action of the ordinary laws of nature. When they do happen in coal mines, or in analogous positions, owing to the interference with the lateral support of the strata worked through, the slips are technically known under the name of "creeps," and they constitute by far the most dangerous, because the most irresistible, of the accidents to which coal mining is exposed.

As slips are principally attributable to the effects of water upon the materials concerned, it must be evident that the only method of preventing or remedying them must be to establish a perfect system of drainage in order to carry off superficial waters without allowing them to soak into the ground so as to dilute the soluble materials, or to set in motion the more minute particles of the intercallated permeable strata. The mode usually adopted near London in dealing with the earthworks to be formed around, or for the support of, waterworks, where of course slips would be of very serious importance, is to carry up the embankment in layers, alternately of the clay in its natural state, and of the clay after having been burnt in a heap; vertical dykes or trenches filled in with burnt clay are carried from the top to the bottom of the bank; and the top is dressed off with the longitudinal and transverse inclinations required to throw the rainwater into a series of surface drains. Theoretically this system is the one to be aimed at in all such works, but it is too often the case that the cost of the precautions it involves induces constructors to neglect some of them; and again it may happen that the materials of the banks are exceptionally impermeable, and thus justify a more economical mode of treatment. Nevertheless, it must be considered that, especially upon ground having a transverse fall, an embankment formed of the London clay is always exposed to slip, unless it should have been executed in some such manner as the one above mentioned. Broken stone or broken chalk may be used instead of the burnt clay; but the condition to be aimed at in the application of those materials is that they should be perfectly permeable, and that the water they may remove should have a free outlet. In deep cuttings, the experience of the New Cross section of the Brighton line proves that the London clay, as it exhibits itself there, will not stand with slopes of less than 4 to 1, even when a good system of superficial drains has been executed. In no case will the stiff blue clays stand with slopes of less than 2 to 1, without giving rise to numerous slips; and those accidents can hardly be prevented, unless the inclination of the slopes is made in the ratio of 3 to 1. An essential precaution to be taken before establishing an embankment of clay is to clear its seating from the vegetable mould which might be originally there, and to provide efficient lateral drains, in order to prevent any land waters from finding their way under the embankment. In order to prevent lateral displacement, or slipping on the bed, on sloping ground, it is frequently the case that toothings are cut in the natural surface, for the purpose of increasing the friction, and thus of opposing the tendency to slip.

The earthwork at the back of retaining walls is frequently so much saturated with water that it has very little more consistency than that fluid itself has; and it is therefore necessary, in order to resist its tendency to slip, to calculate the strength of the wall upon the supposition that the wall is intended to resist the pressure of a semi-fluid mass denser than water. In many places near London, and in seaports upon alluvial deposits, the best rule seems to be to make the thickness of the walls equal on the average to half their height. This rule will hold good with most deliquescent clays, such as the gault, Oxford clay, the clays of the carboniferous series, &c.; all of these are in fact as much exposed to slip as the London clays, from which the previous illustrations have been principally derived.

SLIP, *Ship-Building*. The slips used for ship-building are inclined surfaces (the upper parts of which are kept constantly above the water line, and the lower parts are carried to the requisite depth below the water) for the purposes of building and launching the hull, either into tidal or constantly deep water. They may be placed either in an inclined direction to the line of the shore or normally to it, according to the width of the piece of water into which the ship is to be launched, to the set of the currents, or to the exposure of the situation; and there must always be a clear space of deep water beyond the lower end of the slip, equal to at least twice the length of the vessels to be built on it. In most government ship-building yards several slips are grouped together, in which case they must be separated by level platforms of sufficient width to allow the carpenters to prepare the timber required for the framing, or by platforms of 60 to 100 feet in width, inasmuch as from 30 to 50 feet are required on each side of a ship for this purpose. Wherever it is possible so to place a series of slips, they should be so arranged as to ensure an equal degree of light and heat to the sides of the ships built upon them; for, on account of the length of time a ship is usually upon the stocks, the materials, which might happen to be exposed to a considerable excess of either of those actions, would be likely to have marked differences in their specific gravities at the period of launching; or, in other words, the weights of the two sides of the ship might be very different. The depths of water it has been found advisable to secure over the extremity of the slips at the moment of launching a vessel are considered to be as follows:—

For a first rate three-decker . . .	18 ft. 0 in.
For a two-decker	14 ft. 9 in.
For a frigate	10 ft. 6 in.
For a corvette or small craft . . .	8 ft. 3 in.

But in all cases it is assumed that the hulls are launched "light." The depths, moreover, are calculated by measuring from the under side of the keels; and as the latter are usually placed in a groove of about 3 feet wide by 16 or 18 inches deep, in the centre of the slip, it is only upon the line of this groove that the above-mentioned depths are indispensable.

The sides of a building-slip, respectively on the right and left of the groove for the keel, must in all cases be precisely similar; and, wherever possible, they should be made rectilineal in their transverse section. The longitudinal section should also be rectilineal; and it would appear that the angle of inclination should vary with the weight of the vessel upon the stocks: thus, for three-deckers, an inclination of $\frac{1}{10}$ is necessary, whereas, for frigates, an inclination of $\frac{1}{12}$, or even of $\frac{1}{14}$, would suffice. Very small craft—such as sloops, yachts, &c.—are most conveniently launched, however, from slips having very steep inclinations. It is usual to make the lower immersed ends of the slips for the construction of large vessels about 150 or 160 feet long beyond the end of the portion devoted to the stocks and hull, the latter portion being at the present day made about 300 feet long; so that a building-slip for a large man-of-war is now usually from 450 to 500 feet long at a maximum. The width of the sides of the slips, measured transversely to the line of the keels, should never be less than from one-third to one-half of the maximum breadth of the vessels to be built upon them, and in practice it seems to range between 22 and 28 feet. The platforms on which the timber is worked by the sides of these planes are raised above their level; but in so doing it is essential to observe—1, that any rain-water falling upon them must be carried away from the slip; 2, that no interference must be allowed with the free circulation of air round the hull; 3, that the shores, either for building or for launching, should have a sufficient width of base; and 4, that the vessel, in leaving the ways, should have sufficient space to be able to sway freely within moderate limits.

The majority of the building-slips in English dockyards are at the present day covered, at least in the length occupied by the vessels ordinarily built on them. Of course the dimensions, in length, breadth, and height, of such structures must be regulated by the dimensions of the vessels themselves; and as naval architecture appears at the present day to be in course of change in all these respects, it may be dangerous to pretend even to state any general laws on the subject. It may suffice, then, to mention that, for the old class of 120-gun ships, the roofs over the slips were usually made about 300 feet long by 110 feet clear span between the points of support, and the ridge was usually kept at about 120 feet above the depression for the keel; the framing of the roof must be kept about 6 feet, at least, above the loftiest portion of the vessel; and the opening at the end, through which she has to be launched, must have at least the same amount of clear space in all directions; the side supports of the roof must be placed at such distances apart as to allow the framing which may be put together on the side platforms to be set on end before being carried to their definite positions, and in some of the best slips they are placed at intervals of from 30 to 40 feet. In fact, the conditions to be attained by the roofs erected over building-slips are, that the work and the workmen should be at all times protected from the inclemencies of the weather, whilst there must be an efficient ventilation and a good distribution of light, together with facilities for the transport and hoisting of the materials. The use of iron for ship-building will no doubt greatly modify the details to be adopted in all these matters; but the principles of effectually protecting the whole structure, and of admitting the undisturbed execution of the various manipulations, must remain unchangeable. It would seem, indeed, that iron ships required to be protected from the effects of the atmosphere during their construction even more carefully than wooden ones; and "the fleet of the future" may tax the skill of our constructors to cover their hulls whilst on the slips even more than the old liners have done. Amongst the most important and the most successful covered building-slips, those erected at Woolwich and Deptford may be specially cited.

Some years since, Captain Morton patented what he called "the patent slip," for the purpose of hauling vessels on shore in positions and under circumstances wherein it was requisite to examine and repair their bottoms, and wherein it was either impossible or inexpedient to take the vessels into graving-docks. This slip consisted of the usual inclined way passing down under the high-water line. Upon this way, a platform on rollers, with proper stops, ratchets, and brakes, bearing also iron cradles adapted to receive the ship's sides, was made to work, by means of a steam-engine, in such a manner as to allow the platform to pass under the ship at high-water. The ship subsided into the cradles with the falling tide; and being then carefully wedged into them, it was hauled up upon dry land to be treated as required. Slips of this description have been found to answer remarkably well for vessels of less than 400 or 500 tons burden; beyond those dimensions, the weight of the hulls becomes too great to be economically dealt with in this manner, and it becomes necessary either to resort to the use of the hydrostatic or floating docks, or to take the vessel into a graving-dock, if it should require repairs. Morton's slips are to be found at most of the second-rate ports on our coast, and they are of extreme utility for our coasting-trade.

The most important consideration with respect to the construction of building-slips is, that the floor should remain rigid under any possible load brought upon it; for any inequality in the rate of settlement would not only increase the difficulty of launching, but it might very possibly produce a deformation of the lines of the vessel. As ship-building almost necessarily takes place on the sea-shore, or on the banks of rivers flowing over alluvial deposits, there are very few occasions in which the natural foundations are sufficiently resisting; and it therefore becomes necessary to resort to the use of artificial foundations of some of the descriptions already mentioned. It is under the line of the keel that the greatest strain occurs, and that portion of the foundations must be treated with the greatest attention.

SLUICES. A contrivance used in hydraulic engineering for the purpose of closing, or of regulating the passage of water from one level to another, is properly speaking called a *sluice*, although occasionally when the door itself is upon hinges, or is made to work by machinery, the closing door is called a *vane*, or a *valve*, and the leading passage only is called the sluice. By extension, the word *sluicing* has also been applied to the operation of allowing a large body of water to escape through a sluice with great velocity, for the purpose of removing the light alluvial matters which may accumulate in the outer harbours of a sea-port, or in any analogous position. Properly speaking a lock-gate is a species of sluice; but the usages to which that class of machinery is applied are of so great importance as to have rendered it advisable to treat of its construction and details under the head of CANAL.

As was said under that article, the discharge through a sluice of the ordinary form, (that is to say, of a rectangular section, and without any provision for the effect of the contraction of the fluid vein,) is usually calculated by the formula $Q = ms\sqrt{2gH}$, in which $m =$ a coefficient of 0·625, when only one sluice is used, and of 0·548, when two sluices are used and their streams can meet within a short distance of their points of outlet. This formula, it must also be added, only applies when the sluice discharges into the open air, and there is no head of water on the down side, and it becomes $Q = ms\sqrt{2g\ (H - H')}$ when there is such a head; H representing the depth of water on the up side, and H' the depth on the down side; in both formulæ s represents the area, and g, the accelerating force of gravity. By forming the commencement of the sluice in the manner described by Venturi in his remarks on the effect of *ajutages*, the discharge of single sluices may be increased to such an extent as to make the value of $m = 0{\cdot}984$; but unless the mouth of the sluice be executed in ashlar masonry, or in cast iron, it would be difficult to effect this improvement; and in practice it is rarely attempted. Canal sluices, or sluices for the irrigation or drainage of land, rarely work under great heads of water, and they do not therefore require any very extraordinary precautions in the construction of their channels, or of their machinery; but in the sluices used for scouring harbours, and occasionally in those used for drawing off the water for town supplies, the velocity of efflux renders it necessary to build some portions with particular care. For instance, it is by no means rare to meet with scouring-sluices working with a head of water equal to 16 or 18 feet, and the variable head usually allowed upon the outlet of town reservoirs is equal to 14 feet; under these circumstances the water rushes out with such force as to be able to tear up the surfaces it comes immediately in contact with, and it is therefore indispensable that the tail walls of open sluices, or the materials of closed ones, should be of the most resisting character. The apron at the tail end, and the leading passage of the sluice up to the valves, are in almost all cases executed either in solid masonry, or in iron pipes, to which the framework of the valves is fixed.

In small land sluices, discharging water into tidal rivers, the outlets are frequently closed by flaps hung in such a manner as to open when the head of water on the inside exceeds that upon the outside, but to close directly the outside head preponderates. These flaps, however, are easily liable to derangement by the interposition of extraneous bodies; and they are not therefore used when it is important to shut out external waters under all circumstances. In the latter cases valves working in close grooves, and raised by machinery worked by hand, or self-acting, must be resorted to; and if the area of the water-way should be large—as in the case of scouring-sluices—doors must also be employed. Valves, in fact, are the most suited for closed channels, or aqueducts; turning doors for large areas of water: the former description of machinery is well illustrated in the various works mentioned under WATER SUPPLY; and the latter, in Sganzin's 'Cours de Construction,' and Minard's 'Travaux Hydrauliques des Ports de Mer.'

The question as to the advantages of scouring-sluices for the purpose of removing accumulations in harbours, is one upon which opinions are much divided: for although when the water from the scouring reservoirs is allowed to escape with considerable velocity, it is able to act very energetically upon the materials it may meet in the confined part of the channel; yet directly the stream passes the heads of the jetties it must lose its velocity, and consequently its transporting power. Unless, therefore, there should exist a littoral current able to carry forward the matters scoured out from the inner harbour, a bar must eventually be formed in the zone of still water caused by the interferences of the respective forces of the sluice-waters and of the tides. At the present day, the tendency of modern engineering is to abandon the use of scouring-sluices, and to trust entirely to dredging for the removal of the alluvial matters carried into the ports exposed to that inconvenience. But as there are many occasions in which it might still be advantageous to resort to the use of sluices, it may be as well to add that the principles to be observed in their construction are:—1st. To make the impounding reservoirs of such forms as to insure the prompt discharge of the whole quantity of water they may contain, for which purpose a semicircular basin, with the outlet upon the centre of the chord line, is the most advantageous; 2nd. To make the outlets as large as possible, and to continue the outfall channel as far as may be necessary to conduct the stream, with its full force, against the obstacle to be removed; and 3rd. To place the outlet of the sluices as near to the head of the jetties as may be. The scouring-sluices of Dover, Calais, Dunkirk, Ostend, and the great sluices of Catwyck, through which the waters of the old Rhine are discharged into the German Ocean, are perhaps the most remarkable works of their several descriptions in existence. The reader will find much information on this subject, as also upon the construction of sluices, sluice-gates, valves, &c., in Wiebeking, 'Allgemeine Wasserbaukunst;' Rennie, 'On Harbours;' in Weale's 'Quarterly Papers on Architecture;' Sim's 'Public Works of Great Britain;' D'Aubuisson's 'Hydraulique,' &c.

SLUR, in Music, a curved line (⌒) more or less extended, as may be required, drawn over two or many notes. If placed over two notes on the same line or space, it signifies that the second is not to be repeated, though to be held out its due time. When drawn over notes on different degrees, it signifies that they are to be *legato*, that is, tied—played in a smooth blending manner. This character is sometimes called a *bind*, and also a *tie*.

SMALL-POX (*Variola*). It is a subject of dispute whether this disease was known to the ancients, or whether it has originated at a comparatively recent date. Those who contend for its antiquity refer us to the account of the plague of Athens by Thucydides (ii. 46, &c.) which, they say, is as accurate a description of the leading symptoms of variola as could possibly be expected from any historian who is not a physician. Those who hold the opposite opinion call in etymology to their aid; the word *pock* or *pox*, they say, is of Saxon origin, and signifies a bag or pouch; the epithet *small* in England, and *petite* in France, were added in the 15th century. The term variola is derived from the Latin word *varus*, a pimple, or *varius*, spotted; and, according to Moore, the first authentic passage in which it occurs is to be found in the 'Bertinian Chronicle' of the date 961. The first author, however, who treats expressly of small-pox is Rhazes, an Arabian physician [RHAZES, in BIOG. DIV.] but even he confounded it with measles, and these two diseases continued to be considered as modifications of the same disorder till the time of Sydenham. Small-pox, when it occurs naturally, is preceded by the usual premonitory symptoms of eruptive fevers, such as rigors, pains in the back and loins, prostration of strength, loss of appetite, nausea, and sometimes vomiting, and, in young children, frequently convulsions. About forty-eight hours after the commencement of these symptoms an eruption of small, hard, red-coloured pimples makes its appearance about the face and neck, and gradually extends downwards over the trunk and extremities. The primary fever, as it is called, now lessens, but the pimples increase in size, and become converted into whey-coloured pustules with a depression in their centre. On the eighth day they are at their height, and on the eleventh the matter oozes from them and concretes into crusts, which fall off about the fourteenth day, leaving the skin of a brownish-red colour, and studded with slight depressions or pits. As the eruption travels from above downwards, the parts of the body successively attacked by it become affected with swelling, the mouth waters, and the voice is hoarse; when the incrustation has taken place, these symptoms subside, but a secondary fever commences, which is sometimes more severe than that which preceded the outbreak of the eruption. Small-pox, according to its severity, is distinguished by authors into two varieties, the *distinct* and the *confluent*, *variola discreta* and *confluens*. In the former, the pustules are few in number, well formed, and do not touch each other, and the fever is inflammatory, but mild; in the latter, the disease altogether is more violent, the eruption more general, and the pustules, small and unhealthy, run one into another. The fever likewise is greater, and rather of the typhoid character, is not mitigated on the appearance of the eruption, and is much aggravated at its termination; there is delirium, considerable prostration of the vital powers, ptyalism, inflammation of the fauces, and frequently diarrhœa. Petechiæ and an unhealthy exudation from the body often accompany this form of the disease. Among the mucous membranes, the larynx and trachea suffer much, and children often die of suffocation from this cause; the extent of mucous and of cutaneous inflammation, however, are not always necessarily proportioned to each other. Small-pox rarely attacks the same individual more than once, and, like measles and scarlatina, its consequences are sometimes more to be dreaded than the disease itself. During the secondary fever, an intense form of ophthalmia frequently sets in, which rapidly involves all the structures of the eye, and in the course of a few days destroys its entire organisation. Although it is not common to have both eyes thus affected, still a large proportion of the blind at our public institutions owe their misfortune to this disease. Pleurisy, consumption, scrofula, obstinate diarrhœa, and a fetid discharge from the ears attended with more or less deafness, are the principal diseases liable to result from a severe attack of small-pox. The immediate cause of this disease is a peculiar miasm or poison received into the system from an individual labouring under the same affection, and it is said to make its appearance in from twelve to fourteen days after exposure to the contagion; when, however, it is communicated by inoculation, it appears on the seventh or eighth day. Instances are recorded of mothers who were exposed to the infection of small-pox, communicating the disease to the fœtus in utero, without being themselves affected by it; and, what is equally remarkable, women suffering from small-pox during pregnancy, have brought forth healthy children, who did not take the disease till they were inoculated. Small-pox is frequently epidemic, especially in the spring, and, like all other epidemics, those who are first attacked by it suffer the most severely: it is observed also to be greatly influenced by certain conditions of the atmosphere.

Small-pox can be communicated by inoculation with the matter of its pustules, and the resulting disease being rendered milder by this operation, it was formerly much practised to guard the individual against a spontaneous attack; since, however, the introduction of vaccination by Dr. Jenner, the practice has been deservedly abandoned. Vaccination was supposed by its discoverer to secure the individual permanently and effectually from the contagion of the small-pox; more extended experience has proved, that although it does not always prevent it, yet it so shortens its duration and moderates its violence, that a death from small-pox after vaccination is a rare occurrence. A difference of opinion prevails respecting the character of the eruption which occasionally appears after exposure to variolous infection in persons previously vaccinated. According to many, it is nothing more than chicken-pox; while others affirm that it is really small-pox, although modified by the controlling influence of the cow-pox. The truth appears to be, that "modified small-pox" resembles the chicken-pox in its mildness and duration, but differs from it in its originating from the "variolous germ," and in its power of communicating the true small-pox to others, as well by inoculation as by infection.

The history of the different epidemics of small-pox shows the mortality to be one in four of those attacked who had not been vaccinated; whilst of those who had undergone vaccination the proportion was not one in 450. From the register kept at the Small-Pox Hospital in London, it appears that the mortality at this institution is considerably greater than one in four, having averaged during the last fifty years 30 per cent., the extremes being 18 and 41. From the same source we learn that the greatest number of deaths occurs on the eighth day. Of 168 fatal cases, there died in the first week 32; in the second, 99; in the third, 21; and in the fourth and after, 16. The causes of death at these different periods are the following:—1st week, malignant fever; 2nd week, affections of the throat, and consequent suffocation; 3rd week, or during the secondary fever, febrile excitement, mortification of large portions of the integuments, pneumonia, pleurisy, or laryngitis; 4th, and following weeks, exhaustion, erysipelas, or some of the diseases before enumerated as liable to result from small-pox. It was formerly supposed that the eruption of variola was not confined to the skin, but invaded also the internal parts; this is not the case, the internal affections are simply inflammatory, and do not partake of the specific character of the cutaneous disease.

No peculiar plan of treatment is required for small-pox; it is that of ordinary fever: cleanliness, free ventilation, an attention to the strength of the patient, and a watchfulness against accidental complications, are the principal points to be kept in view. During the eruptive stage of the disorder, the bowels should be kept moderately open by saline aperients, and the occasional exhibition of a mild mercurial. The temperature of the skin may be regulated by cool air, or by sponging it with tepid vinegar and water; if there should be much unpleasant effluvium from the surface of the body, washing it with a weak solution of one of the chlorides will be found to correct this. It has been recommended by some writers, and has been long a practice in Eastern countries, to pierce the pustules with a fine needle; this procedure, it is said, lessens the violence of the secondary fever, and prevents pitting. M. Serres, with the same object, directs the application of lunar caustic to the pustules on the fourth day. As a general rule, we should say that venesection is not admissible at any period of small-pox; indeed we have no hesitation in affirming that some of the severest consequences of the disease may be averted by a judicious employment of measures of an opposite tendency to blood-letting. The sloughing of the integuments, and the intense ophthalmia, rapidly terminating in entire loss of vision, are eminently connected with an enfeebled and cachectic state of body; and the best mode of averting these evils is to have recourse early to those remedies which are most efficacious in arresting their progress. Hence quinine, combined with the mineral acids, sarsaparilla, wine, brandy, if the powers are much reduced, and animal food, if the patient can eat it, must be perseveringly administered. It may not be out of place here to mention that the character of the ophthalmia termed *variolous* has only lately been pointed out to the profession by Mr. Marson of the Small-Pox Hospital. It had been supposed that the eye was lost in small-pox from one or more of the pustules of this disease forming on the cornea. Mr. Marson has shown not only that this never takes place, but that the loss of vision is attributable to ulceration or sloughing of the cornea, which comes on generally about the eleventh or twelfth day of the disease. The patient is nearly always in a state of great debility, and requires tonic medicines and nutritious diet to give him a chance of escaping from the destructive effects of this ophthalmia.

SMALT. A silicate of potash coloured by means of oxide of cobalt in various shades of blue, which being reduced to powder is used in painting and varnishing porcelain and earthenware, for imparting a blue colour to glass, and in various other applications in the useful arts. The manufacture, which is a curious one, is minutely described by Mr. Tomlinson, in a paper read before the Society of Arts, London, and inserted in the 'Pharmaceutical Journal' for April, 1851. The materials are carefully prepared, and are melted in pots in the glass furnace, with occasional stirring. The combination of the materials by melting or smelting gives the origin of the word smalt from the German, *schmelzen*, "to melt," or the substantive *schmelz*, which means "enamel." Smalt or smalts is called also *schmelz* or *schmalz-blau*.

When the glass attaches itself to the workman's rod, and can be drawn out into threads, it is ready for pouring. The glass gall or sandiver is skimmed off, and the several metallic impurities of the cobalt subside; the latter being afterwards separated, form an article which is known in commerce by the name of *speiss*. It is variable in its composition; but may contain cobalt, nickel, iron, arsenic, bismuth, and silver. The blue glass is taken out of the glass pots in iron ladles, and poured into water in order that it may be readily pulverised. After this it is crushed at a stamping mill, sifted to the size of ordinary sand, and then ground in a mill between horizontal granite stones for from four to six hours. The powder thus produced is transferred to large vats of water, and in a few minutes a separation of particles takes place, the heaviest, or those richest in cobalt form a deposit, which constitutes one of the commercial varieties of smalt, known as *azure*, *coarse blue*, or *streu blau*. The number of minutes required to form this deposit varies with the season, it being somewhat longer in winter, when the water is colder and denser than in summer. The water above the deposit, holding finer particles, is drawn off into other vats and allowed to subside for a time, varying from three-quarters of an hour to an hour and a half, according to the quality of powder required. The term *farbe* or "colour" is applied to these deposits. The water is again drawn off into reservoirs and allowed to remain for an indefinite length of time, the deposit being known by the name of *eschel* or "blue sand."

The colours thus obtained are all again subjected to the action of water—*washing over* or *elutriation*, as it is called,—before they are fit for the market. "Each deposit is agitated in tubs abundantly supplied with water, and is then left to subside for a length of time, which experience has taught will produce the particular variety required. During the subsidence, any floating impurities are separated by means of a fine horse-hair sieve. The water is then carefully decanted off into another vessel; the deposit just formed is treated with fresh water if necessary; and all these waters in their turn, on being drawn off, deposit different varieties of smalt, either in the form of farbe or eschel." The various precipitates being taken out of the vats and drained are placed on shelves in a warm room or they are dried spontaneously in an airy loft. The hard masses thus formed are crushed and sifted, placed in a hot room with occasional stirring, and when dry are taken to a room in which are arranged a number of squares containing the different shades of smalt with their numbers. The sorting is followed by a final sifting, and the smalt is packed in small casks of half a hundred weight each. The powder is moistened with a little water to prevent waste, and the cask is marked with the name of the shade.

It may be remarked that artificial ultramarine [ULTRAMARINE] has superseded some of the uses for which smalt was formerly in large demand.

SMELLING SALTS. [AMMONIA.]

SMELTING. The processes of smelting, or extracting metals from their ores, are described under the names of the principal metals, such as COPPER; LEAD; METALS; IRON; &c.

SMILACIN. ($C_{16}H_{15}O_6$ or $C_{18}H_{15}O_6$). *Salseparin. Pareglin.* A peculiar principle found in sarsaparilla (*Smilax Sarsaparilla*). It exists in the form of colourless needles, is inodorous, very soluble in water and in alcohol, when boiling, but less so when cold. It dissolves in ether and volatile oils; the fixed oils dissolve it sparingly.

Smilacin dissolves in weak acids and alkaline solutions, and separates from them unaltered when they are neutralised. Nitric acid partly decomposes it. Sulphuric acid colours it first deep red, then violet, and afterwards yellow; water precipitates it unaltered.

SMILAX, *Medical Properties of.* Though, according to Dr. Hancock, but one species of this rather extensive genus yields the genuine sarsaparilla, it is quite certain that the roots of many are collected, and pass under that name in commerce. Most species of smilax are provided with spines, which has given origin to the first half of the name in the Spanish language, *zarza*, a bramble, and *parilla*, a vine, from its climbing or turning habit. Sarza has been adopted as the familiar name in the 'London Pharmacopœia,' which indicates *S. officinalis* (Humbt., 'Nova Genera et Species,' i.) as the source of the officinal article. This view is ably maintained by Dr. Berthold Seemann in the 'Botany of the Voyage of H.M.S. Herald,' London, 1852-57. The different kinds of sarsaparilla are better known by the course they follow in their progress towards European consumption, than by their botanical history. In describing them it seems best therefore to adopt their commercial names.

1. *Jamaica, or Red, Sarsaparilla.*—This occurs in bundles formed of the root alone, folded in a roundish mass, about a foot or more in length, and four or five inches broad. Each bundle is formed by the roots and rootlets (fibrillæ, or beards, as they are technically termed), without any portion of the rhizoma (or chump) or of the aërial stem. The roots are long, slender, about the thickness of a small quill, with a dark-brown furrowed or wrinkled bark. The bark is thick, easily separable from the ligneous part beneath. The ligneous part is of a light red, which assumes a deeper hue when moistened. It is easily split longitudinally, and has a whitish centre or medulla, containing more or less starch. But for the absence of medullary rays and of nodi, this root might be taken for the twigs of an exogenous plant, to which the structure of the smilaceæ approximates in several other points. A transverse section exhibits the cuticle and epidermis, which are separated from the inner or ligneous circle by a zone of cellular tissue; then the duramen, which presents the cut or open extremities of numerous ducts; and lastly, the medulla, or pith, in the centre. The duramen, though porous, is of a denser texture than that of the Honduras sarza. The taste is at first sweetish or slightly mucilaginous, then nauseous, resembling ipecacuanha, but not very acrid or bitter. No variety of sarza has any odour, but dirty or unwashed specimens have a faintly earthy smell.

The powder is a light reddish-brown, which, when triturated with water and tincture of iodine, changes to a blue, but of less intense depth than the Honduras sarza, indicative of a smaller proportion of starch in the former.

According to Mr. Pope ('Trans. Medico-Chir. Society,' xii., p. 349), "the whole medical efficacy resides in the bark; and the root, deprived of its cortical part, contains only pith and tasteless woody-fibre." The tasteless character of the wood renders this statement very probable. He further says: "The corticle part gives out nearly the whole of its virtues by cold infusion in distilled water, very readily to lime-water or water slightly impregnated with caustic alkali; and that boiling distilled water extracts all its virtues." He deems the quantity of extract yielded by any specimen the criterion of its excellence. Judged by this standard, the Jamaica sarza is manifestly the best. His experiments have been confirmed by those of Mr. Battley, and by Thubeuf. Jamaica sarsaparilla is the produce of the Spanish Main, and thence sent to Jamaica to be forwarded to Europe. Some has been cultivated in that island, but it is of inferior quality. The *Smilax officinalis* (Humbt.), which is conjectured to be the parent plant of the wild root, grows in New Granada, on the banks of the Magdalen river, near Bojorque.

2. *Lisbon, Para, or Brazilian Sarza.*—The term Lisbon sarza was also bestowed on the sort just described, for as Lisbon sarza was till lately most esteemed, the former on its first introduction was vended under that name. The true Lisbon sarza is the produce of *Smilax syphilitica*, which grows both in New Granada, on the river Cassiquiare, between Mandacava and San Francisco Solano, and in Brazil, on the Yupura and Rio Negro, by which last name it is sometimes designated. (Martius, 'Reise,' iii., pp. 1213, 1280.) The Indians collect it all the year round, dry it over a moderate fire, and tie it into bundles with the flexible stem of a plant called Timbotitica. To prevent its being attacked by insects, they hang it up at the gables of the houses, and sometimes gently smoke it. These bundles have a neat appearance externally, but the interior is filled up with the chump and other rubbish. The fibres vary in thickness from that of a straw to that of a crow-quill, with little beard, and fewer longitudinal wrinkles than the Jamaica sarza; the colour, a light, sometimes a dirty grayish-yellow, or reddish-brown colour, internally white; the cortical part mealy, including a thin cellular layer, which, with the duramen, is also white. Taste at first insipid, but on prolonged mastication a sort of acrid guttural taste, without bitterness, is experienced. This kind contains more starch than the Jamaica variety, and yields a paler infusion.

3. *Honduras Sarza* was the kind first introduced into medical practice, a circumstance which still leads many persons to prefer it. It generally comes over in very large bundles, weighing from one hundred to one hundred and fifty pounds, but sometimes in small round bundles. Each piece has the chump and the numerous roots proceeding from it. The chump is often two inches thick, woody, hard, and insipid. The roots are from two to four feet long, mostly thicker than those of the Jamaica or Lisbon kinds. The outer part is a dirty grayish-yellow, sometimes verging to brown or reddish. The cortical part is very easily separable from the ligneous; between the epidermis and the duramen is a thick white amylaceous layer, whence a large quantity of flour or starch falls when the piece is broken across; hence the term *mealy*, applied to this variety. A transverse section exhibits a great many cut extremities of ducts, which run parallel, and are so continuous, that air can be blown from one end to the opposite of a considerable piece. This kind has no odour, and the taste is at first merely starchy and insipid, but at last acrid and guttural. The rhizoma (or chump) is altogether tasteless. The fibres and the bark are rendered black by iodine; while the rhizoma is not affected by this re-agent. The decoction of the roots is changed to an intense blue by a solution of iodine. "A strong decoction of Honduras sarza forms a copious precipitate (starch) on addition of alcohol." (Pereira.)

4. *Vera Cruz Sarza* is not common in the English market, but is occasionally sold under the name of Lisbon sarza. It is the produce of *Smilax medica* (Schlecht), which grows abundantly on the eastern slope of the Mexican mountains. Externally the fibres are more furrowed than the Jamaica. The transverse section is denser in the young roots, and it is not mealy; there is little beard. The chump is always attached. It yields a deep-coloured decoction, which is unchanged by a solution of iodine. The sarsaparilla of the Caracas of French writers is deemed to be the Vera Cruz sort.

5. A kind called *Lima Sarza* is brought in considerable quantity to this country, and greatly resembles Jamaica sarza, for which it is said by Dr. Pereira to be extensively sold, and from which it differs chiefly in yielding a less quantity of extract.

It is manifest that the *S. sarsaparilla* (Linn.), which is a native of the southern states of the American Union, yields none of the article used at present in Europe, though it may yield a portion of what is used in the United States. But this is denied to be used in the United States by Dr. Wood, though indicated in their Pharmacopœia, and Willd., iv., 776 referred to.

Besides the above-described varieties, the produce of different species of smilax, there are numerous spurious or false sarsaparillas, some from known, others from unknown sources. Italian sarza is the root of *Smilax aspera*, the only species native of Europe. It is a very worthless kind, and owes its reputation to a mistake by which it was considered to be the source of the Indian sarza, a truly valuable root, but which is the produce of an asclepiadeous plant, *Hemidesmus indicus*. German sarsaparilla consists of the rhizoma of one or more species of Carex, *C. hirta* and *C. arenaria*. It may easily be distinguished from the genuine by the numerous nodi, which are absent from the smilax.

The active properties are mostly due to the salseparine, the resin, and, when present, to the volatile oil. The more acrid and bitter any specimen of sarza is, the better.

The virtues of sarsaparilla are the subject of much diversity of opinion; many practical men deeming it very useful, while others consider it nearly worthless. This difference seems owing partly to its being employed in different diseases by the one set, from those in which it is used by the other, and still more to inherent differences in the particular root used. It is collected at all seasons of the year, and in all stages of its growth, circumstances which cannot fail to influence its qualities; as young roots gathered before the flower appears must differ greatly from old roots gathered after flowering. But a more important cause of difference exists in the mode of preparing it for administration. The long period enjoined in the 'London and Edinburgh Pharmacopœias' for boiling the root is most injurious, and in reality the order is never obeyed by any of the chemists or druggists who have obtained a reputation for their preparations. They either use water of a temperature far below that of boiling, or perfectly cold water, as ordered by the Dublin Pharmacopœia, and recommended by all the most eminent continental pharmaceutists. The powder is not thus injured, but its bulk and taste are obstacles to its full employment. The compound syrup of the latest edition of the American Pharmacopœia is a most excellent form as an addition to some of the watery preparations. A mixture of preparations made with both hot and cold water seems best, as these menstrua dissolve out different principles. Preparations made *in vacuo* are also commendable, and for keeping long either a hydro-alcoholic compound fluid extract is good, or the same brought to a solid state, which diminishes the bulk, and so fits it for exportation.

The efficacy is sometimes heightened by the introduction of a small quantity of bichloride of mercury—a very objectionable proceeding, as a person taking mercury ignorantly, may expose himself to cold and run extreme risk of life.

The curative powers of sarsaparilla are often very much heightened by combination either with alkalies, especially lime-water, or in other cases with acids, particularly the nitric. When properly prepared, and administered in suitable cases, no one can doubt the efficacy of sarsaparilla. From the high price of it, and the great consumption, attempts have been made in many of the great hospitals to dispense with it or discover a cheaper substitute, but without success. In the worn-out or debilitated systems so common in the patients by whom these establishments are crowded, its utility is daily manifested. This is partly owing to the care taken to procure the best kinds, and partly to the appropriate use made of it, for the sake of economy. It is chiefly used in chronic, syphilitic, rheumatic, gouty, and cutaneous diseases. Its most obvious action is diaphoretic, but if the patient be kept cool, diuretic. In cases where an acid is indicated, the *Hemidesmus indicus*, which is possessed of a natural acid (hemidesmic acid), will be found a useful substitute for the artificial preparations.

If any European plant ever prove a proper substitute for sarsaparilla, it will probably be the *Tamus communis*, or black bryony of our hedges, the root of which, when scraped and applied externally as a poultice, rapidly promotes absorption of effused blood. This is well known to bruisers, gypsies, and others, who to remove ecchymoses of the eye apply a poultice of this root, and generally remove the blackness in twelve or twenty hours. (Tyrrell 'On the Eye,' vol. i., p. 200.)

A long list of plants used as substitutes is given by Th. Martius in his 'Pharmakognosie. In many cutaneous diseases petroleum will be found quite as efficacious. It is far cheaper and taken in smaller doses. Pariglin, or smilacin has been recommended by Palotta, but it has not come into much use.

SMOKE BALLS. [Light Balls.]

SMOKE; SMOKE-PREVENTION. Smoke is the vapour arising from substances in a state of combustion. In its more extended sense the word is applied to all the volatile products of combustion, which consist of gaseous exhalations charged with minute portions of carbonaceous matter, or soot; but the term is frequently employed to express the carbonaceous matter only. It is important to bear this distinction in mind, as it involves a fact which appears to have been sometimes overlooked: namely, that however completely the soot may be destroyed, and the smoke be thereby rendered invisible, it still remains necessary to provide means of free exit for the deleterious gases. The action of an ordinary chimney in conveying the smoke from a fire situated at its lower extremity is very simple. The air in the chimney, being rarefied by the heat, becomes lighter in proportion to its bulk than the surrounding atmosphere, and therefore rises: its place being supplied by fresh air forced in at the lower end by the pressure of the comparatively heavy cold air outside the chimney. A constant rising current is thus created, the force of which is sufficient to carry up with it any light bodies, such as the particles of soot which escape from the fire. The intensity of this current depends much upon the height of the chimney; for it is evident that the higher a chimney is, within reasonable limits, the greater must be the difference between the weight of the column of hot air which it contains, and that of a column of cold air of equal elevation. It is also evident that the hotter the air in the chimney is kept, the more rapidly it will rise. Hence chimneys act better when built in stacks, or when in the interior of a house, than when single, or when outside the walls.

The circumstances which impede the proper action of chimneys, and occasion the annoyance of smoke in houses warmed by common open stoves, have excited the attention of many individuals, and formed the subject of several treatises. Franklin analysed the subject very judiciously, and published a pamphlet pointing out nine causes, or kinds of cause, for the evil. 1. The want of a free supply of air to the bottom of the chimney. It is of little consequence how spacious the room may be into which the chimney opens, if the access of fresh air to the room be cut off. As the hot air escapes from the top of the chimney, its place must be filled by fresh air taken from the room. But if the entrance of the external atmosphere be insufficient, every chimney-full of air abstracted from the room lessens the density of what remains, so that the draught will decrease until the air in the chimney and that in the room are of equal density; after which it will cease altogether, and the smoke will no longer ascend. This inconvenience can only be remedied by providing openings for air commensurate to the demands of the fire. Whenever it is practicable, the best situation for them is near the top of the room, and over the fire-place; because the entering air is then warmed by the warm air which rises to the top of the room, and becomes pretty generally diffused. The object may be attained by leaving a window a little open at the top, or by providing long narrow openings above the window or immediately beneath the cornice. Another plan is the use of a pane of glass in the window, hinged to the frame at its lower edge, and capable of being opened more or less as required; side-pieces of glass being added to prevent the air from entering laterally. Sometimes a number of strips of plate-glass, so arranged as to resemble a Venetian blind, are used; these being so placed as to throw the air upwards. The common ventilator, or *whirligig*, answers the same purpose, and diffuses the air in some degree by its rapid revolution, occasioned by the action of the current upon its inclined vanes. 2. Many chimneys smoke because the opening at the lower end is too large. While a small opening to a tall chimney increases the draught to an improper degree, and causes a wasteful consumption of fuel, a large opening to a short funnel will allow the smoke to escape into the room; because all the air required by the chimney may enter at one side of the opening, leaving the other side free from current, and therefore allowing the smoke to puff out. In such a case the draught is weakened by the coldness of the air which enters the chimney at such a distance from the fire as to be very little affected by it. This defect must be remedied by contracting the opening. 3. A third cause of defective action is the funnel or chimney being too short. The same effect is produced when the flue from an upper story is turned into one from a lower room. The inconvenience of such an arrangement may be somewhat diminished by a contrivance for closing the collateral flue when not in use. The shortness of a chimney may sometimes be rendered harmless by contracting the entrance, so that all the air entering it shall be highly heated, by passing immediately over the fire. 4. Different chimneys in the same house occasionally overpower each other. If we suppose two stoves, each having a distinct chimney, in a room without a sufficient supply of air from without, we may conceive that one fire becoming stronger than the other, may overpower it, and obtain a supply of air down the chimney of weakest draught; the descending current of course blowing the smoke of the weaker flue into the room. Precisely the same effect will take place if the stoves are in different rooms; provided there be, owing to the opening of the doors, a communication between them. This will account for the common case of a parlour chimney smoking whenever the room-door is opened, although it may act properly when the room is closed, and thereby cut off from the effect of the kitchen chimney. The proper cure is clear; if every room have a free supply of air from without, there will cease to be any probability of the chimney of one apartment overpowering that of another. 5. Another cause arises from the situation of the house. If a house stand under the brow of a hill, or in the vicinity of a much higher building, the wind, passing over the higher obstacle, beats down into the chimneys of the sheltered house, and so prevents the exit of smoke. This may sometimes be remedied by raising the chimney, and in other cases by means of a cowl, or turning-cap, the opening of which always turns from the wind. The ordinary cowl is turned by means of a vane attached to its upper part; but one patented by Mr. Pollard is turned by wheels set in motion by the action of the wind upon the oblique vanes of a rotatory flyer. Another contrivance consists of a square box placed on the top of the chimney, each side of which is a door, hinged at one edge, and connected, by means of an iron rod, with the door on the opposite side of the box: in such a way that when one door is closed by the force of the wind, the opposite one opens, and allows the smoke to escape. 6. Chimneys occasionally smoke from a cause just the reverse of that last described. This occurs when the chimneys are low, and stand between the wind and a high building, or neighbouring edifice, so that the air is dammed up, as it were, round about them. Raising the chimneys appears to be almost the only alternative. 7. Another cause of smoking is the injudicious arrangement of the door or doors of a room. If the door be on the same side as the fire-place, and occasion it to smoke by sending a current across the front of the stove, either it must be altered so as to open in the opposite direction, or a screen must be used between it and the stove. 8. Smoke is sometimes blown down a chimney which is out of use. This arises from the circumstance that a stack of chimneys usually maintains a more uniform temperature than the surrounding air. When in the middle of the day, the air generally becomes warmer than that in the chimneys, the current moves *downward*, carrying with it smoke that may happen to be passing over, or escaping from a neighbouring flue. A plate or register, closing the bottom of the chimney when out of use, obviates this inconvenience. 9. Chimneys, which under ordinary circumstances perform very well, occasionally smoke in consequence of the passage of a strong wind over them, which the force of the rising vapour is insufficient to cope with. Among various modes of cure adopted, one is to make the top of the flue funnel-shaped, with a view to facilitate the escape of the smoke under such circumstances; another, to reduce the opening at the top to a long narrow slit. Probably a cowl might be of use in such a case.

The nuisance occasioned by the smoke of coal-fires has formed a subject of complaint from the earliest times in which mineral fuel was extensively used; and the great increase of steam-engine and other furnaces, consequent on the extension of manufactures, has afforded, of late years, additional ground for attempts to abate the nuisance. Such attempts are important, not only for the purification of the air, but also for the economy of fuel; since the matter which gives smoke objectionable density and colour is unconsumed fuel in a finely-divided state. It appears, therefore, that if a supply of air could be thrown into a fire in such a way as to occasion the combustion of the carbonaceous matter, the result would be that a greater amount of heat would be obtained from a given quantity of fuel, at the same time that the nuisance of smoke would be abated. It may be observed, that the quantity of smoke emitted from furnace-chimneys varies much with the state of the fire, being greatest when a mass of fresh fuel is thrown on, and least when the fire has burned clear or the fuel is fully ignited. Attention to this circumstance, on the part of the stoker, will greatly diminish the nuisance; because, if he throw on the fresh fuel in a thin layer, it will the sooner become perfectly ignited; and, by laying it in the fore part of the furnace, the dense smoke arising from it has to pass over that part of the fire which is in a state of more perfect combustion, and is thereby in a great measure consumed. Many of the contrivances introduced or suggested as smoke-consuming furnaces act on these principles; arrangements being adopted to insure the right feeding of the fire without much attention on the part of the firemen.

James Watt was one of the first to obtain a patent for a smoke-consuming or smoke-preventing apparatus. He caused the smoke of the fresh fuel, in its way to the chimney, to pass, together with a current of fresh air, over fuel which had already ceased to smoke, and was intensely hot; by which means the smoke, by coming into close contact with the hot fuel, and being mixed with the current of fresh air, was converted into pure flame, free from smoke. Since that time innumerable plans have been brought forward for introducing the necessary supply of air to the furnace; but while many of them accomplish the purification of the smoke as completely as could be desired, many others increase the consumption of fuel or weaken the draught of the furnace. If the air admitted to the furnace be cold, it diminishes the heat of the fire; and if hot, expense is incurred in heating it, whether this be effected by a separate fire or by passing the air in pipes through the chimney. Most railway companies are required, by their acts of incorporation, to avoid the emission of smoke from their engines; and this is usually done, at great expense, by the use of coke. To lessen this expense, Mr. Chanter devised a plan, consisting in the introduction of a *deflector* dipping into the burning fuel, which compels the smoke from the crude coal to pass through a mass of burning coke, supplied through a small door, and conducted at once to the back of the furnace. By this means three parts of coal may be used to one of coke, with very little risk of much smoke.

Another mode of destroying smoke is by injecting steam into the furnace. The plan has been tried by several inventors, among others by Mr. Iveson. In his apparatus, the steam is thrown into the fire in several minute jets, from a fan-shaped distributor in the fore part of the furnace. The steam not only destroys the smoke, but also greatly increases the intensity of the fire. Thus the necessity for a large chimney is obviated, it being only necessary to provide a small passage for the escape of the gaseous products of combustion. Experiments on the same furnace, with and without the injection of steam, indicate a saving of fuel to the amount of 33 per cent.; the consumption in five hours being respectively 558 and 812 lbs. As a drawback from this saving, the plan requires, in a steam-engine furnace, about one-tenth of the steam generated, and in other furnaces renders necessary the erection of a small boiler. It is proposed, in high-pressure engines, to make use of the waste steam for the purpose of injection.

Besides the numerous plans for the combustion of smoke, various methods have been tried on a limited scale for conducting it to a distance from the buildings in which it is formed, by means of subterraneous channels; and for condensing it by means of a shower of water, so that the sooty matter might be conveyed away by the sewers.

In 1819, a committee of the House of Commons was appointed "to inquire how far it may be practicable to compel persons who use steam-engines and furnaces in their different works to erect them in a manner less prejudicial to public health and comfort." The committee, in their Report, noticed, among other plans, that of Mr. Steel, in which the fuel was supplied in a constant stream, by means of an inclined hopper; the quantity of coal supplied in a given time, and the size of the pieces, being regulated by a grooved roller. The fuel was distributed over the bed of the furnace by the motion of the grate itself, which was of a circular form, and turned on a central pivot. The committee, after much investigation, reported that efficient means for destroying smoke had been "satisfactorily and effectually obtained." An act of parliament was passed to enforce the use of smoke-consuming apparatus; but it was very little attended to, and the smoky condition of our great towns increased quite as rapidly as the increase of population and manufactures. After many years had passed, the Commons appointed another committee of inquiry in 1843. This committee examined a large number of scientific and practical men, among whom were Dr. Faraday, Dr. Arnott, Professor Brande, Dr. Ure, Admiral Parry, Dr. Reid, Mr. Jukes, Mr. Solly, Mr. Muntz, and Mr. Houldsworth. Nearly all concurred in opinion that smoke may be nearly prevented, either by existing methods or by apparatus easy to devise. Voluntary associations had been formed in many large manufacturing towns, including Leeds, Bradford, and Manchester, to put down the nuisance. In numerous factories there was a positive saving of fuel effected by the avoidance of smoke; but most of the manufacturers declared that the apparatus hitherto employed had not fulfilled the promises made. The committee recommended an act of parliament, but none was passed at that time. In 1844, before the Health of Towns Commission, Mr. Thos. Cubitt (than whom few men were more thoroughly versed in the philosophy of house-building) advocated smoke-prevention very energetically, as being practically attainable, morally obligatory, and financially profitable. Another committee sat in 1845, followed by an attempt to pass a smoke-prevention act; but this was frustrated by certain influential manufacturers, who did not like the trouble attending the adoption of new apparatus. When the Health of Towns' Act was passed, clauses were introduced which empowered town-councils to attack the smoke nuisance in their own way, and within the limits of their own towns; and many places availed themselves of this power. After other minor attempts at legislation, acts were passed in 1853, 1856, and 1857, rendering it compulsory to adopt smoke-preventing contrivances. Two of these acts related to the metropolis and one to Scotland. Certain trades were exempted from the operation of the statutes, and certain dates were named on which the penalties for non-observance would begin to be enforced. Not only furnaces employed in trades and manufactures, but also steam-boats working above London Bridge, were brought within the scope of the acts relating to the metropolis. The police received certain powers in relation to this matter, and the provisions of the acts were sought to be enforced by penalties.

Improvements have resulted from these legislative enactments; but the evil is still far from being removed. There seem to be difficulties attending the enforcement of the law. Those manufacturers, whose furnaces are arranged on the old plan, protest against the expense necessary for adapting the smoke-preventing apparatus; and they are not slow to declare that the several inventions fail in some or other of the requisite conditions. On the other hand, the statements are most clear and positive that the evil *can* be prevented, and that a saving in fuel rewards those who resolutely make the attempt. Printers, woollen spinners, builders, metal-founders, button-makers, sugar-refiners, steam corn-millers, porter brewers—all have placed upon record the declaration that gain as well as cleanliness results from the adoption of smoke-preventing apparatus.

We shall make no attempt to describe the numerous forms of apparatus patented within the last few years. All of them belong to one or other of two classes. They attempt either smoke-*consumption*, by supplying the heated smoke, at a particular spot, with fresh air enough to kindle and consume it; or smoke-*prevention*, by so supplying fuel that it may ignite without forming smoke at all. Jukes' apparatus belongs to the latter class.

The inventions of Dr. Arnott would call for some attention here, were it not for the fact that his ingenious stoves and ventilating apparatus had better be described under WARMING AND VENTILATION, in connection with many other kinds of apparatus for similar purposes.

SMUGGLING is the clandestine introduction of prohibited goods, or the illicit introduction of goods by the evasion of the legal duties. Excessive duties present an overwhelming temptation to men to evade them; and the law loses a great part of its moral influence when it first tempts to violation of it and then punishes the offence. The true remedy is a wise tariff. It annihilates at once a traffic which no ingenuity can ever put down; for all experience proves that so long as a profit can be made by smuggling sufficiently high to counterbalance the necessary risk, it will not fail to flourish. The decrees of Berlin and Milan, instead of annihilating commerce, only forced it into extraordinary channels. Silk from Italy, for example, instead of being received in England by the most direct means, often arrived by way of Archangel and Smyrna; in the former instance being two years, and in the latter twelve months, on its passage. Sugar, coffee, tobacco, and cotton-twist were despatched from England to Salonica, and thence conveyed by horses and mules through Servia and Hungary to Vienna, from which place they were distributed over the Continent, in defiance of the rigorous decrees of Napoleon; it might happen that coffee was consumed at Calais which, instead of being sent direct from London, arrived by the above circuitous route.

We have only to examine the tariff of any country to know if smuggling is practised; and if a bad system of commercial policy has been long pursued, there the smuggler will be found. The *contrabandista* of Spain figures in novels and tales of adventure. In no country is the illicit trade so general and extensive. The exports to Gibraltar from England are very large, and a great proportion is introduced by smugglers into the interior. Nearly the whole of the tobacco imported into Gibraltar is smuggled into Spain, where the article is one of the royal monopolies. On the French frontier the illicit trade is equally active.

The vicinity of France and England, and the injudicious character of their respective tariffs, long encouraged smuggling to a large extent on both sides of the Channel.

The reduction of the duties on silks, tea, spirits, wines, and numerous other articles, has done more to repress smuggling than all the efforts of the revenue officers aided by a large armed force.

The present acts relating to smuggling are 3 & 4 Wm. IV. c. 53, and 4 & 5 Wm. IV. c. 13.

SNOW. It has been stated [RAIN, vol. vi. col. 925] that rain, snow, and hail are formed by the precipitation of vapour when two volumes of air of different temperatures, and saturated with moisture, become mixed together; the nature of the precipitation depending on the resultant temperature and on that of the region of the atmosphere through which the aqueous particles descend towards the ground. Now when the precipitating water is frozen into crystals of ice, united together in such a manner as to reflect light to the eye in great abundance from all, thus producing a sensation of whiteness, the assemblages of crystals constitute snow. In all probability it is formed by the immediate freezing of aqueous vapour, without the sensible intervention of the liquid state. Proximity to the earth's surface is not required for its production; Mr. Green, the aeronaut, met with a severe snow-storm at the height of a mile and a quarter. The formation of snow through a considerable tract of the atmosphere appears at a distance as a bluish, sometimes indigo-blue, haze.

M. Monge observes ('Annales de Chimie,' vol. v., p. 1), that the crystallisation of sal-ammoniac presents phenomena similar to those which are observed in the formation of snow. If a saturated solution of sal-ammoniac in a warm state be allowed to cool in a tranquil air, the surface of the liquid is that which first arrives at a state of supersaturation, and there the first crystals are formed; these sink immediately, and in descending they unite with similar crystals formed in the liquid itself, so that they arrive at the bottom of the vessel in white flakes.

The flakes of snow usually consist of brilliant spicular icicles, which diverge from a centre in six directions, and resemble stars having so many rays, upon each of which small crystals are sometimes formed; but if the atmosphere is agitated, the original flakes strike against each other, and uniting in groups by regelation [ICE], in consequence of small quantities of moisture adhering to them, they descend in irregular forms. In regions of the earth far to the north or south, the air, when allowed to enter through a small aperture into a heated apartment, has frequently caused the warm vapour to be converted into snow. ('Bibliothèque Universelle,' 1830.)

Beccaria observed that his apparatus for ascertaining the electrical state of the atmosphere indicated the presence of electricity in snow as well as in rain; and, according to the observations of Schübler, it is more commonly positive than negative. The lightness of the flakes, by which they float about in the air when agitated, is the result of their surface being great when compared with their volume. The sp. gr. of snow has been stated to be very variable; and according to Musschenbroek, that of some, of the stelliform kind, was only $\frac{1}{24}$ of the specific gravity of water, but this must have been the specific gravity of the mass, a mixture in fact of air and ice; and M. Quetelet has since found that the greatest density is nearly $\frac{1}{2\cdot8}$ of that of water, the temperature being 34·5° (Fahr.). He ascertained also that the density of fine snow having no determinate form was about $\frac{1}{4}$, the temperature being 32°, and that the least density varied from $\frac{1}{10}$ to $\frac{1}{12}$ of that of water, at which time the snow had the form of small stars, and the temperature varied from 29·7° to 18·5°. It is, however, difficult to understand these results; it would appear that they also must relate to an aggregate of snow and air, as there is no reason why the specific gravity of crystals of snow should differ greatly from that of ice, which is always crystalline, and has the sp. gr. 0·918.

Snow has been observed to fall in a fine powder, not having any appearance of regular crystals, and sometimes in grains, as fine as those of what is called basket salt.

The flakes have, even in temperate regions, many varieties of form, and are often very elegant; but the polar regions of the earth are those in which it has been supposed that nature has displayed her power in creating this species of beauty in the highest degree and to the greatest extent. In the 'Phil. Trans.,' 1775, may be seen numerous delineations of the figures assumed by flakes of snow as they were observed by Dr. Nettis, of Middelburg in 1740; but the late Rev. Dr. Scoresby, in his 'Account of the Arctic Regions,' has given still greater varieties; the latter gentleman, besides dividing them into classes, has also expressed their magnitudes, and the state of the barometer and thermometer when the snow fell.

Of these classes the first is called "lamellar," and is divided into many different species: one of the latter is a thin transparent hexagonal plate, or a hexagonal plate with white lines parallel to the sides of the polygon, and sometimes there is a starlike figure in the centre; the magnitudes vary, and the greatest is about $\frac{1}{10}$ inch diameter. Another species, and this is the most ordinary appearance of snow, is the stelliform; the figures 1, 2, and 3 represent some of the most remarkable varieties of this kind; its magnitude varies, but the diameter of the greatest is about $\frac{1}{3}$ inch, and it occurs most abundantly when the temperature of the air is near the freezing point of water. Sometimes the stars appear to have twelve points, but Dr. Scoresby thinks that these are formed merely of two stellar plates applied one on the other The six following figures represent assemblages of hexagonal crystals the diameters of the first two kinds are respectively $\frac{1}{10}$ and $\frac{1}{20}$ inch and those of the rest are $\frac{1}{3}$ inch diameter; they are usually formed at temperatures between 32° and 20° (Fahr.).

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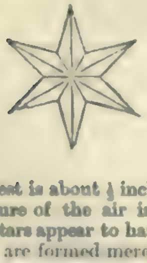

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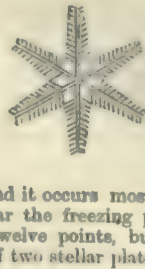

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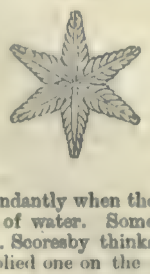

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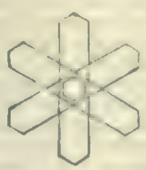

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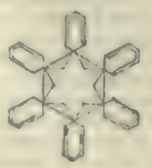

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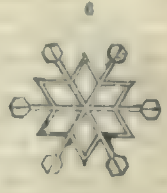

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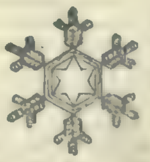

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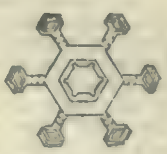

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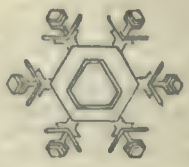


The second class is also lamellar, but it differs from the former in having a spherical nucleus, either transparent or white, about $\frac{1}{4}$ inch diameter; and sometimes spicular radii proceed from thence in different directions at angles of 60° with each other. The temperature at which this class is formed varies also from the freezing-point to 20° (Fahr.).

The third class consists of spiculæ or six-sided prisms; of these, the finer sort, which are formed at the temperature of 28°, resemble white hairs very delicate and clear, and about $\frac{1}{4}$ inch long; the coarser kinds are formed in the lower region of the atmosphere, at about the freezing temperature.

The fourth class is of a pyramidal form and about $\frac{1}{30}$ inch high, but Dr. Scoresby could not determine whether the base was triangular or hexagonal. The fifth class consists of hexagonal crystals united together by a slender spicular crystal, so as to resemble two wheels with an axle. Both of these kinds are very rare. Dr. Scoresby saw the latter only twice and the former only once.

M. Huber Burnand, speaking of the character of the snow which fell at Yverdun in 1829 and 1830, states that it was crystallised in stellar plates with six rays, along each of which were disposed filaments arranged like feathers, and these again supported finer filaments similarly arranged; the plates, which were extremely thin, were perfectly plane and regular. ('Bibl. Univ.,' 1830.) It is also related in the same work, that in 1829 the frost at Yverdun assumed every day a different form, being sometimes disposed in parallel groups or fillets; sometimes it resembled leaves, and occasionally spines about an inch long, which were terminated by a flat rosette with six divisions.

The severe weather experienced in the vicinity of London, and over the south-west and eastern parts of England at the beginning of the year 1855, of which no parallel had taken place since that of 1814, which it greatly resembled, as well for depression of temperature as for the duration of the frost, was remarkable also for the peculiar character and continuous fall of snow, which first made its appearance on January 16th, and lay on the ground till after the end of February. We are indebted to Mr. Glaisher, the Secretary of the British Meteorological Society, for a particular account of this snow and its crystals, which is annexed to the Report of the Society read at the fifth annual meeting, May 22, 1855. Much of this snow, Mr. Glaisher observes, was "of that peculiar character which former writers designated Polar Snow, it having been chiefly composed of crystalline particles, which they supposed to be confined, with rare exceptions, to the Arctic regions. This supposition, however, is not supported by the recent prevalence of innumerable crystals, that have exhibited a degree of crystalline formation equal to any that has been recorded in colder latitudes. . . . . . The primary figure or base of each crystal I determined to be a star of six radii, or a hexagon of laminæ, and the compound varieties to include combinations of spiculæ, prisms, cubes, and rhomboids, aggregated upon and around the central figure, according to the degree of its complexity." The paper is illustrated by 88 small and 63 greatly enlarged figures of the snow crystals, the joint productions of the pencils of Mr. and Mrs. Glaisher, and probably the most valuable series of such representations extant. The figures above, copied from Dr. Scoresby, 6, 7, and 8, it will be observed, have an inner tracing of the hexagon. Similar crystals to these were observed by Mr. Glaisher, who had not seen them previously, nor any figures of them, except those of Dr. Scoresby of those seen by him in the Arctic Seas. But the forms of snow-crystals are doubtless dependent on the temperature of the air and the amount and distribution of the aqueous vapour it contains, the differences in those respects of the different strata of air, the interchange of currents, and other physical circumstances, and not otherwise upon difference of locality than as that may involve a difference in those circumstances. The forms ordinarily characteristic of the snow of one latitude or region may be produced in any other, wherever snow can occur. It does appear, however, that the most regular and complex stellate aggregations accompany the lowest temperatures. The extraordinary complexity of many of these crystals of snow, when considered in connection with the principle of regelation which governs the union of separate portions of ice, leads to the suspicion that infinitesimally small crystals result from the solidification of vapour, which undergo accretion and are subsequently incorporated with each other by regelation, in directions accordant with those of the crystalline forces to which the elementary forms are due. The crystallography, however, of solid water, or ice, which of course is that of snow, is at present in a condition of singular contradiction. We appear not to know with certainty to what system of crystallisation it should be referred, or even whether it does not belong to more than one system; though there is strong evidence that it must belong, in part at least, to the rhombohedral system, to which it has usually been referred. The facts known respecting it will be stated with the other properties of ice, in the article WATER.

Snow, in the form of cylinders and spheres or spheroids, has been occasionally observed in North America. The former were produced by the snow deposited in a second shower upon some which had previously fallen, and the surface of which had been covered by a thin coating of ice. A violent wind then caused the particles of snow to roll on the ice, and the masses thus produced assumed perfectly cylindrical forms of various sizes, the greatest being 2½ or 3 feet diameter; they were hollow at each end. The spherical balls were from 1 inch to 15 inches in diameter, and were also formed chiefly by rolling, though some were found in enclosures where they could not have rolled, and, therefore, they are supposed to have been formed in the atmosphere itself; they were very light, and were composed of crystals irregularly united. (Silliman's 'Journal,' vols. ii. and vi.) Similar balls were observed in East Lothian, in 1830, by Mr. Sheriff; and this gentleman relates that they were composed only of snow, for one of them being cut through was found to have no hard body for its nucleus. ('Edin. Phil. Journal,' ii. 58.) Mr. Luke Howard records an instance, in which, with the surface at 33° or 34°, and during a strong wind, the snow, instead of driving loose before the wind, was collected occasionally into a ball, which rolled on, increasing till its weight stopped it: thousands of such balls were seen lying in the fields, some of them several inches in diameter. The balls of snow, torrents of which constitute what are called rolling avalanches [AVALANCHES], appear to be formed in a similar manner, though by means chiefly mechanical, in addition to regelation, which must have place in all these accretions.

When an extensive tract of country is covered with newly-fallen snow, its glare has a painful and injurious effect on the eyes, from which the traveller has to guard them by a crape veil, the natives using various similar means of protection. It is, however, from such snow alone that much inconvenience is felt, indicating, probably, that it is owing to the light reflected from the myriads of facets which the crystals of snow present. Dr. Joseph D. Hooker remarks, that he has never suffered inconvenience from this cause in crossing beds of old snow, or glaciers with weathered surfaces, which absorb a great deal of light, and reflect comparatively little, and that little coloured green or blue. The changes to which snow is subject after descending to the ground, according to the circumstances of temperature, weather, exposure, and the nature of the surface upon which it has fallen, are evaporation, liquefaction, and conversion into a compact ice. It evaporates at all temperatures. Mr. Howard found a circular area, of five inches diameter, to lose 150 grains troy from sunset to sunrise, and about 50 grains more by the following sunset, the temperature varying from 18° to 30°. This evaporation probably supplies the vapour which appears in the form of mist after a snow-fall, and also that which is condensed again in the form of a secondary fall of snow.

The process of conversion of snow into glacier ice has been noticed in the article GLACIERS, in NAT. HIST. DIV. A similar conversion, in localities of a different character, has been observed by Dr. Hooker, who describes the beds of perennial snow in the Sikkim Himalaya, which extend below the true inferior limit of perpetual snow (see the following article), as having great resemblance to glaciers, from which, indeed, he considers them undistinguishable. Though broad and convex, and occupying mountain slopes,—not filling hollows like glaciers commonly so called,—they display the ribboned structure of glacier-ice, and descend at a rate and to a distance depending on the slope and on the amount of annual accumulation behind. [CLOUD; HAIL.]

SNOW, PERENNIAL, or PERPETUAL. In the article CLIMATE (col. 968–70), a general view of this subject has been given, together with particulars of the elevation of the snow-line under different latitudes and in different localities, both as indicated by theory and shown by observation. We are now enabled to enter in a more precise manner into the consideration of the varying circumstances which govern the position of the snow-line, and also into the special history of perpetual snow as it exists about and upon the greatest and highest mountains of the globe. For the materials of these we are chiefly indebted to Dr. Joseph D. Hooker, who, in the Appendix to his 'Himalayan Journals,' has treated the subject with views at once more general and more philosophical, perhaps, than have been applied to it since the original investigations of Wahlenberg, Von Buch, and Humboldt; and has largely illustrated them by the facts of the distribution of snow in Nepaul, Tibet, and the Himalaya, which are stated in their appropriate places in his 'Journals' themselves.

It must be premised that three things are frequently confounded together in popular science and in books of travels. First, the elevation in the atmosphere, or above the general surface of the earth, as defined by the level of the sea, of the temperature of 32° Fahr., or the freezing point, for each latitude, as affected by the distribution of land and sea, from which, in union with the solar temperature, results the temperature of each isothermal line at the surface.

Secondly, the position of the inferior limit of the beds of perpetual snow—the actual snow-line in this sense—on mountainous elevations, as dependent on the cause just assigned, in conjunction with local causes on the great scale, and as existing in fact at that particular elevation for each region, below which all the snow that falls melts. This may be considerably below or considerably above the line of 32°.

Thirdly, the altitude at which much snow is *perennial*, in the ordinary sense of the word—its permanence arising from local and from temporary (though recurrent) meteorological causes—masking, by its extension downwards, the true limit of perpetual snow as defined above. It is requisite, however, for the due apprehension of the subject, that the distinction between these three things should be carefully preserved in the mind.

Dr. Hooker has stated his belief ('Him. Journ.,' vol. ii., p. 394), "that the limit of perpetual snow is laid down too low in all mountain regions, and that accumulations in hollows, and the descent of glacial ice, mask the phenomenon more effectually than is generally allowed." He defines the limit, "in general terms only, as being that where the accumulations are very great, and whence they are continuous upwards, on gentle slopes. All perpetual snow, however," he continues, "becomes ice, and, as such, obeys the laws of glacial motion . . . . .; whence it follows, that the lower edge of a snow-bed placed on a slope is, in one sense, the termination of a glacier, and indicates a position below that where all the snow that falls melts. . . . It is impossible to define the limit required with any approach to accuracy. Steep and broken surfaces, with favourable exposures to the sun or moist winds, are bare much above places where snow lies throughout the year; but the occurrence of a gentle slope, free of snow, and covered with plants, cannot but indicate a point below that of perpetual snow." A careful examination of those great beds of snow in the Alps, from whose position the mean lower level of perpetual snow, in that latitude, has been deduced, convinced Dr. Hooker that they are winter accumulations—of the kind alluded to above, due mainly to eddies of wind—of far more snow than can be melted in the following summer, being hence perennial in the ordinary sense of the word only. It follows that the true limit of perpetual snow is much higher in the Alps than it is usually supposed to be. He proceeds to show that the altitude of the limit in the Alps has been stated by Professor James Forbes more than 1000 feet in defect, the Jardin, on the Mer de Glace, at the elevation of 9500 feet, being evidently below the limit, to which, however, Professor Forbes had assigned the elevation of 8500 feet only.

Proceeding to the principal scene of Dr. Hooker's own researches, we find that there are two secondary considerations which materially affect the melting of snow, and therefore exert a material influence on the elevation of the snow-line, but which have not been sufficiently dwelt upon, though they bear directly upon the great altitude of that line in the most elevated regions. From the imperfect transmission of the heating rays of the sun through films of water, it follows that the direct effects of the rays, in clear sunshine, are very different at equal elevations of the moist outer and dry inner ranges of the Himalaya. Secondly, naked rock and soil absorb much more heat than surfaces covered with vegetation, and this heat, radiated from them again, is much more rapidly absorbed by the white snow than the direct heat of the sun's rays is. Hence, at equal elevations, the ground heats sooner, and the snow is more exposed to the heat thus radiated in arid Tibet than in the wooded and grassed mountains of Sikkim. In the latter region, "the position and elevation of the perpetual snow vary with those of the individual ranges, and their exposure to the south wind. The expression that the perpetual snow lies lower and deeper on the southern slopes of the Himalayan mountains than on the northern conveys a false impression. It is better to say that the snow lies deeper on the southern faces of the individual mountains and spurs that form the snowy Himalaya. The axis itself of the chain is generally far north of the position of the spurs that catch all the snow, and has comparatively little snow on it, most of what there is lying upon north exposures." Thus appears to be at last explained the apparent anomaly that the snow-line ascends in advancing north to the coldest Himalayan region; the position of the greatest peaks and of the greatest mass of perpetual snow being generally assumed, though erroneously, as indicating a ridge and watershed. "Travellers arguing from single mountains alone, on the meridional ridges, have at one time supported and at another denied the assertion, that the snow lies longer and deeper on the north than on the south slope of the Himalayan ridge."

The enormous accumulation of snow in Sikkim at 15,000 feet exercises a decided influence on the vegetation, preventing its extension upwards, which, in other situations, takes place to 16,000 and 17,000 feet. Glaciers descend to 15,000 feet in the tortuous gorges which immediately debouch from the snows of Kinchinjunga, but no plants grow on the *débris* they carry down, nor is there any sward of grass or herbage at their base, the atmosphere immediately around being chilled by the snows, and the summer sun rarely warming the soil. In the vicinity of Kinchinjhow, 21,000 feet high, and where the mean level of perpetual snow is 19,000 feet, coinciding, probably, with a mean temperature of 20°, the glaciers do not descend below 16,000 feet, but a green sward of vegetation creeps up to their bases, and herbs grow on the patches of earth they carry down, while dwarf rhododendrons cover the moraines. Dr. Hooker concludes on this subject with the following general statement :—"Looking eastward or westward on the map of India, we perceive that the phenomenon of perpetual snow is regulated by the same laws. From the longitude of Upper Assam in 95° E. to that of Kashmir in 75° E., the lowest limit of perpetual snow is 15,500 to 16,000 feet, and a shrubby vegetation affects the most humid localities near it, at 12,000 to 14,000 feet. Receding from the plains of India and penetrating the mountains, the climate becomes drier, the snow-line rises, and vegetation diminishes, whether the elevation of the land increases or decreases; plants reaching 17,000 and 18,000 feet, and the snow-line 20,000 feet. To mention extreme cases : the snow-level of Sikkim in latitude 27° 30′ is at 16,000 feet, whereas in latitude 35° 30′ Dr. Thomson found the snow-line 20,000 feet on the mountains near the Karakoram pass, and vegetation up to 18,500 feet—features I found to be common also to Sikkim in latitude 28°."

The progress of physical geology brings before us, from time to time, the conditions of the earth's surface at former periods. An example of this, probably involving the consideration of the great extension of snow and ice in the northern hemisphere, southward from the arctic regions, at what has been termed the glacial epoch, as alluded to in several former articles, is stated by Dr. Hooker nearly in the following terms :—Were the snow-level in the Dingcham province of Tibet as low as it is in Sikkim, or 15,000 feet, the whole of Tibet, from the Donkia mountain northwards to the Yaru-Tsampu river, the average direction of which is west and east nearly in the latitude of 29° 10′, "would be everywhere intersected by glaciers and other impassable barriers of snow and ice, for a breadth of fifty miles, and the country would have no parallel for amount of snow beyond the Polar circles. It is impossible to conjecture what would have been the effects on the climate of northern India and central Asia under these conditions. When, however, we reflect upon the evidences of glacial phenomena that abound in all the Himalayan valleys at and above 9000 feet elevation, it is difficult to avoid the conclusion that such a state of things once existed, and that at a comparatively very recent period." Valuable information on this subject, as well as on the philosophy of the snow-line as at present existing, will be found in Mr. W. Hopkins's paper, "On the causes of changes of climate," 'Quart. Journ. of Geo. Soc.,' vol. viii., p. 76-87.

SNOW, RED. [See Nat. Hist. Div.]

SNUFF. [Tobacco.]

SOAP MANUFACTURE. Soap originally meant the compounds derived from the union between fatty bodies and the alkalies potash and soda. Although the name is still usually thus limited in its meaning, it has nevertheless been extended to compounds of oleaginous bodies with some earthy and metallic bodies, having but few properties in common with soap properly so called.

Properties.—It has been found by Chevreuil that different varieties of fatty matter consist chiefly of two kinds: one hard, to which he gave the name of *stearin*; and the other soft, which he termed *olein*. He also discovered that stearin is composed of stearic acid and a peculiar principle which, on account of its sweet taste, he named *glycerin*; and it was further proved by his experiments that olein consists of oleic acid and glycerin. Stearin is therefore a stearate of glycerin, and olein an oleate of the same substance. When, in the manufacture of soap, an alkali (soda, for example) is heated with tallow, the soda gradually dislodges the glycerin from combination with the stearic and oleic acids, and by combining with them, forms soap, or, in other words, a compound of stearate and oleate of soda, and the glycerin remains in solution.

In vegetable fat oils—olive-oil, for example—the glycerin is combined with margaric and oleic acids, forming margarate and oleate of glycerin; and, consequently, soap made with this oil is a margarate and oleate of soda, instead of a stearate and oleate of this base.

The soaps which have the alkalies for their bases are soluble in water, though the solution is in general milky; they are also soluble in alcohol, and the solution is used frequently as a test of what is called the *hardness* of water. [Soap-Test.] Acids also decompose soaps, and though the effect is apparently similar, yet it is in reality different: thus when sulphuric acid is added to soap, a white precipitate is formed, but this is merely the fatty acid which the soap contained, and shows the change which the fat employed has undergone; it is either stearic, oleic, or margaric acid, &c., or a mixture of two or more of them. Sulphate of soda remains in solution when a soda soap has been thus decomposed. There are certain preparations used in medicine under the names of emulsions and liniments, which are obtained by merely agitating either ammonia, potash, soda, or lime-water, with oil. The first of these is an ammoniacal soap; the second and third are imperfect alkaline soaps; and the fourth is an earthy soap to which barytes and strontia-water form compounds nearly analogous; these earthy soaps are insoluble in water, or nearly so. Metallic soaps are formed by heating certain metallic oxides, as those of lead, mercury, and bismuth, with fatty matter; glycerin is separated, as has already been mentioned, and the metallic soaps formed are insoluble in water. The only soap of this kind extensively employed is that of oxide of lead, which is largely used under the name of diachylon, or lead plaster.

Manufacture.—Some of the soap-factories of the present day carry on operations with the aid of considerable chemical and mechanical skill. There is, however, not much that requires description here.

Mottled soap, a kind much used in England, is made of tallow, kitchen stuff, soda, water, and a little salt. The tallow principally employed is brought from Russia, and arrives in a solid state in barrels; it is tolerably pure, and is ready for use at once. The impure grease known as kitchen-stuff requires much heating, straining, and purifying before it is fitted for use; and even then it is not employed for the better soaps. The alkali formerly used, as has already been stated, was obtained from kelp and barilla; but the carbonate of soda obtained from common salt is now almost exclusively used. The soda being required almost in a caustic state, the carbonic acid is driven off for the soap-maker's purposes. The caustic soda is dissolved in water to form a *ley* or *lye*. The ley is pumped into boilers, and mixed with the fatty substances. Steam-heat is applied, and the mixture is boiled until the fat has combined with all the alkali of the ley. The spent ley is pumped up, fresh ley is introduced, and the boiling proceeds. This is repeated several times, a stronger ley being used each time than before. When the soap is nearly finished, the "mottling" is given by sprinkling a small quantity of very dense ley; this percolates slowly through the mass, leaving dark-coloured veins in its track. When the soap is finished, it is laded into buckets, and thence transferred to *frames*. These frames are upright oblong boxes, made either of wood or iron, and easily taken to pieces. The soap, when the frames are full, is allowed to cool and solidify. Each frame being taken to pieces, the mass of soap, sometimes weighing as much as three or four thousand pounds, is exposed to view. It is cut up into slabs or layers by a wire being drawn through it, following the marks of certain gauge-lines. The application of a similar wire in a different way afterwards separates the slabs into bars about 15 inches long, 3 inches wide, and 3 inches deep.

Curd or *white* soap is made nearly in the same way as mottled, but with a more careful selection of ingredients, and a better management of some of the processes.

Yellow soap is distinguished from the others by the large amount of resin and palm-oil contained in it. The casks of palm-oil, as brought from Africa, are placed over a trough with the bung-hole downwards; the steam-pipe is admitted, and the melted substance flows out. The oil is bleached by a chemical process, and then the soap-making proceeds as before. The resin and the palm-oil both serve the purpose of tallow, and are the cause of the relative cheapness of yellow soap.

Soft soap, used principally in the woollen manufacture, is made chiefly of oil and potash. The oil may be whale, seal, olive, linseed, or any that comes most readily to hand, and is combined with a little tallow to increase the stiffness. Soft soap is not shaped in frames, but is poured at once into barrels or casks.

Fancy soaps, as they are called, such as are sold by perfumers, are generally made from good white soap, remelted, and modified by the addition of perfumes, &c.

Dr. Normandy in 1841 patented an invention for using up all kinds of gums and resins in soap by the addition of sulphate of soda. He made hard soap cheap by that means; but his operations were checked by the Excise insisting on the same rate of duty as was paid for the high-priced soaps. His patent, not having been a profitable one, was renewed in 1855 for three years.

A substance called *soap bark* was brought to Europe from some tropical country in 1859. It is black without, and yellowish white within, very heavy and dense. When the white layers are macerated in water, they produce an emulsion which, when mixed with oil, may be used as soap.

Soap Trade.—The soap manufacture is one of considerable importance. The principal seats in England are Liverpool and Runcorn, London, Brentford, Bristol, and Hull. Nearly three-fourths of the total quantities of soap are made at these places; but there are also manufactories of considerable extent at Bromsgrove, Newcastle, Gateshead, Warrington, and Plymouth. In Scotland, two-thirds of the total quantity of soap are made at Glasgow and Leith.

In 1711 an Excise duty of 1*d.* per lb. was first imposed on all soap made in Great Britain, which was raised in 1713 to 1½*d.* per lb. In 1782 the duty was again increased, and a distinction was, for the first time, made between hard and soft soap, the duty on the former being 2½*d.*, and on the latter 1¾*d.* per lb. In 1816 hard soap was subjected to a duty of 3*d.* per lb. In 1833, the duty was 1½*d.* per lb. on hard soap, and 1*d.* per lb. on soft. The interference of the Excise in the manufacture of soap was, until recently, exceedingly arbitrary and vexatious; but in the 'Seventeenth Report of the Commissioners of Excise Inquiry,' 1835, the discontinuance of the system of survey which then existed was recommended. The act 3 and 4 Vict. c. 49, passed in 1840, repealed seventeen other acts, so far as they concerned the making of soap. The article may now be made in any way or of any material which the manufacturer thinks most judicious, as the Excise does not interfere with the process of manufacture.

When the duty on hard soap was 3*d.* per lb., the selling price averaged about 6*d.*, out of which another ½*d.* was absorbed in duties on the tallow and other substances used in the manufacture. The 3*d.* duty, as has been stated, was reduced to 1½*d.* in 1833; and in 1853 the duty was wholly repealed. In 1852, the last year for which official returns are obtainable, rather more than 200,000,000 lbs. of soap were made in the United Kingdom; of which the largest items were—London and vicinity, 54,000,000 lbs.; Liverpool and vicinity, 47,000,000 lbs.; Glasgow and vicinity, 16,000,000 lbs. The export of soap is not large; for the three years, 1858, 1859, 1860, it varied from 160,000 lbs. to 190,000 lbs.

The increasing use of palm oil is perhaps the chief commercial novelty in the soap manufacture.

SOAP, *Medical Uses of.* In pharmacy and medicine the term soap is applied to combinations not only of oily and fatty matters with the alkalies soda or potash, but also with the volatile alkali (ammonia), lime (an alkaline earth), and metallic oxides, especially oxide of lead; likewise to solutions of resins in liquid potash, such as guaiacin [GUAIACUM], called therefore *Sapo guaiacinus.* The combinations of oils with ammonia or lime, being very thin, are generally termed *liniments;* the common one of hartshorn with oil is an example of the former, while oil and lime-water constitute the common application to burns termed Carron oil, from its frequent employment in the great iron-works at that place. The combination of oil with oxide of lead is generally termed a *plaster.* Some combinations of a volatile or fixed oil with an acid are sometimes called soaps, such as that of oil of turpentine with hydrochloric acid (artificial camphor), or of almond oil with sulphuric acid (*Sapo acidus*): but these are scarcely entitled to be so regarded. Among continental pharmaceutists, many cerates and mixtures of metallic salts with common soap are termed *soaps,* but they are more correctly called plasters.

Of hard soaps, the fine kinds are made with soda and the purer vegetable oils, and the inferior kinds with animal oils or the coarser vegetable oils or resins. White soda soap is prepared with caustic soda and olive oil (in Spain) or with almond oil (in France). In its purest state it is called *medicinal* soap; in a less pure state, it is called Alicant, Venice, or Spanish soap. The Castile or marbled soap has this appearance communicated to it by sulphate of iron and red oxide of iron being added and stirred through it when the soap is nearly made. These are impurities which render it less fit for medical use in many cases than the white soap. When properly prepared, white soap should neither make an oily mark on paper nor have a burning alkaline taste. It should be perfectly soluble in pure water and in alcohol. [SOAP-TEST.] When an alcoholic solution is evaporated, the residuum constitutes *transparent* soap.

White soda soap is the only one which should be used internally. It is chiefly employed to form pills, which are gently aperient and antacid; their power in this latter respect is greatly increased by the addition of exsiccated carbonate of soda: this combination is of great utility in the treatment of gouty and calculous disorders, when an alkali is indicated. In other cases it is used to prevent the pills becoming hard and insoluble; such as compound rhubarb pills. White soap furnishes a ready antidote to the strong mineral acids, in cases of poisoning by any of these.

Soft soap is directed by the London Pharmacopœia to be made with potash and olive oil only, but this order is seldom complied with. The soft soap, in which both soda and potash are used, is made with olive and other oils and tallow. It is employed only to form the compound sulphur ointment. Soft soap is of great service in many cutaneous diseases, several of which, when in a mild form, may be cured by it alone. It may be rendered still more useful by the addition of sulphur or sulphuret of potash (liver of sulphur). In the treatment of scabies, porrigo (ring-worm), and such diseases, this application is far superior to the ointments and other greasy compounds commonly employed, which increase the filth or uncleanness by which the disease is aggravated. It is also much cheaper. Many other soaps are vended, pretending to special qualities, such as glycerine soap, tar soap, &c. Soap formed of cocoa-nut oil has the great advantage of being soluble in salt water, and so can be used at sea.

SOAP-TEST. A solution of white curd soap in proof spirit; it is used in ascertaining the amount of hardness of waters.

The action of hard water upon soap has already been alluded to. [CALCIUM, *carbonate of lime.*] By using a solution of soap of known strength, and adding it to a given quantity of hard water until no more of the familiar curdy precipitate is thrown down, the amount of hardness will obviously be at once indicated. The method of preparing and applying this soap test is as follows:—

Sixteen grains of pure carbonate of lime are dissolved in pure hydrochloric acid, the solution evaporated to dryness on a water bath, the residue re-dissolved in water, again evaporated to dryness to ensure the absence of free acid, and the residue now dissolved in one gallon of distilled water. The resulting liquid is a solution of hydrochlorate of lime, or, more correctly, chloride of calcium, but the amount of lime in it is identical with that in the sixteen grains of carbonate of lime, and inasmuch as all soluble lime salts act similarly upon soap, that is, without any influence of the acid contained in them, it follows that the gallon of chloride of calcium solution accurately represents a natural water whose hardness is due to sixteen grains of carbonate of lime in a gallon. All that is now necessary is to ascertain how much of a dilute alcoholic solution of soap must be added to a given quantity of the chloride of calcium solution before a permanent lather is produced. This being done the soap-test has henceforth a value given to it, inasmuch as if it be added to any hard water, equal in volume to that of the artificial hard water previously experimented with, until a permanent lather be produced, the amount so added indicates the number of grains of carbonate of lime present in the gallon. The quantity of water tested is usually and conveniently one thousand grains, and the soap-test is used to greatest advantage when poured from a burette divided by transverse markings into measures each containing ten grains: the soap-test should, moreover, be so diluted by its proof-spirit solvent, that thirty-two measures require to be added to one thousand grains of the artificially prepared standard solution of sixteen degrees of hardness before complete precipitation of the lime is produced and a permanent lather formed.

In applying the soap-test to a normal water, the specimen of the latter should be placed in a bottle of five or six ounces' capacity. The solution of soap must then be added in small portions at a time and the mixture well shaken in the intervals. When indications of a lather appear on the surface of the liquid, the additions of soap-test must be very small, and finally when a lather is produced that does not subside until after the bottle has remained undisturbed on its side for three minutes, the amount of soap-test added is noted; an inspection of a table similar to the one here appended at once indicates the degree of hardness per gallon.

CLARK'S SOAP TEST-TABLE FOR HARDNESS OF WATER.

Degree of Hardness.	Measures of Soap Test.	Difference for next Degree of Hardness.
0. (Distilled water)	1·4	1·8
1. ,,	3·2	2·2
2. ,,	5·4	2·2
3. ,,	7·6	2·0
4. ,,	9·6	2·0
5. ,,	11·6	2·0
6. ,,	13·6	2·0
7. ,,	15·6	1·9
8. ,,	17·5	1·9
9. ,,	19·4	1·9
10. ,,	21·3	1·8
11. ,,	23·1	1·8
12. ,,	24·9	1·8
13. ,,	26·7	1·8
14. ,,	28·5	1·8
15. ,,	30·3	1·7
16. ,,	32·0	

Excess of carbonic acid in a water is apt to decompose a lather once formed and an experiment may be thus interfered with. To avoid this source of error Professor Clark, who is the author of the process now described, recommends that the water be violently agitated before the addition of the soap-test, the superstratum of air being two or three times renewed by suction through a glass tube. When a water is of more than sixteen degrees of hardness it should be diluted with its own bulk of distilled water before proceeding with the addition of soap-test.

Salts other than carbonate of lime confer hardness upon water, moreover an equal number of degrees of hardness is produced by very different amounts of the several salts. Thus, to produce ten degrees of hardness the annexed quantities of the following salts are necessary:—

Carbonate of lime	10·0	grains.
Sulphate of lime	13·6	,,
Nitrate of lime	16·4	,,
Chloride of calcium	11·1	,,
Carbonate of magnesia	8·5	,,
Sulphate of magnesia	12·1	,,
Chloride of magnesium	9·6	,,

Inasmuch, however, as it is only the relative hardness of a water that is usually required to be known, unnecessary complication is avoided by representing that hardness in degrees, the value of which has been conventionally agreed upon by chemists. One degree is the amount of hardness that would be produced by one grain of carbonate of lime in a gallon of water: two degrees by two grains, and so on.

SOCAGE, or SOCCAGE, is service rendered by a tenant to his lord for lands, the principal ingredient of which is its being fixed and determined in its nature and quality. The certainty of the service distinguished socage from tenure in chivalry, or by knight's service, on the one hand, and from tenure in pure villeinage by arbitrary service, on the other; and therefore Littleton says, § 118, "A man may hold of his lord by fealty only; and such tenure is a tenure in socage; for every tenure which is not a tenure in chivalry is a tenure in socage."

Socage is said by old writers to be of three kinds: socage in frank tenure; socage in ancient tenure; and socage in base tenure. The propriety of the last denomination is however doubtful. The second and third kinds are now called respectively tenure in ancient demesne and copyhold tenure. The first kind is called free and common socage, to distinguish it from the two others, though as the term socage has long ceased to be applied to the two latter, socage and free and common socage now mean one and the same thing.

Besides fealty, which the tenant in socage, like every other tenant, is bound to do when required, the tenant in socage, or, as he was formerly called, the socager or sockman, is bound to give his attendance at his lord's court baron, if the lord holds a court baron either for a manor [MANOR] or for a seigniory in gross. This obligation to attend the court, it is supposed, gave rise to the name of the tenure, but the question is not without doubt.

Both forfeiture and escheat are incident to tenure in socage, as they were also to tenure by knight's service. In that species of socage tenure which is called gavelkind there is no forfeiture.

Wardship is also incident to this tenure. But this incident is not, as formerly in knight's service, a benefit given to the lord, but a burden imposed on the infant's next friend of full age, who must however be a person not capable of inheriting the estate upon his young kinsman's death.

In particular districts some of the incidents of tenure by knight's service were by custom annexed to the tenure in socage. Thus in the diocese of Winchester the lord claimed the wardship and marriage of his socagers.

Before the abolition of feudal burdens by the Commonwealth, confirmed upon the Restoration by 12 Car. II. c. 24, tenants in socage were bound to pay 20*s.* upon every 20*l.* of annual value, as an aid for making the lord's son a knight, and the same for marrying the lord's eldest daughter. This tenure was also subject to the payment of fines upon alienations.

By the above statute, the provisions of which were extended to Ireland by the Irish act of 14 and 15 Car. II. c. 19, tenure by knight's service was abolished, and all lands, with the exception of ecclesiastical lands held in free alms [FRANKALMOIGNE], were directed to be held in free and common socage, which, with the limited exception in favour of lands held in frankalmoigne, is now the universal tenure of real property throughout England and Ireland, and those colonies which have been settled by the English.

It is true that a large portion of the soil of all those countries is held by leaseholders, and in England also by copyholders; but the freehold of the land held by leaseholders and copyholders is in their lords or lessors, who hold that freehold by socage tenures.

SOCIAL CONTRACT, or ORIGINAL CONTRACT. Locke thus expounds his doctrine of the social contract ('Essay on Civil Government,' c. 8, 'Of the Beginning of Political Societies'): he says that "men being by nature all free, equal, and independent, no one can be put out of his estate and subjected to the political power of another without his own consent." By *can* he does not mean to say that it may not happen that one man shall be subjected to the political power of another, but that he cannot properly or justly be subjected without his consent; which appears from what follows:—"Whosoever therefore out of a state of nature unite into a community must be understood to give up all the power necessary to the ends for which they unite in society, to the majority of the community, unless they expressly agreed in any number greater than the majority. And this is done by barely agreeing to unite into one political society, which is all the compact that is or needs be between the individuals that enter into or make up a commonwealth. And thus that which begins and actually constitutes any political society, is nothing but the consent of any number of free men capable of a majority to unite and incorporate into such a society. And this is that, and that only, which did or could give beginning to any lawful government in the world." This doctrine is open to obvious objection. The conclusion as to the origin of "*lawful* government" by implication contains the notion that some governments are not lawful, whereas all men must and do admit that all governments which can maintain themselves are governments, and the term lawful is not applicable to that power which can declare what is lawful. The two objections which Locke mentions as being made to the theory are, 1.—"That there are no instances to be found in story of a company of men independent and equal one amongst another, that met together, and in this way began and set up a government." 2. That "it is impossible of right that men should do so, because all men being born under government, they are to submit to that, and are not at liberty to begin a new one." Locke replies to both objections with considerable ingenuity, but there are few political writers at present who will be inclined to consider his answer conclusive.

Hume, in his 'Essay on the Original Contract,' admits that "the people, if we trace government to its first origin in the woods and deserts, are the source of all power and jurisdiction, and voluntarily, for the sake of peace and order, abandoned their native liberty, and received laws from their equal and companion. The conditions upon which they were willing to submit were either expressed or were so clear and obvious that it might well be esteemed superfluous to express them. If this, then, be meant by the original contract, it cannot be denied that all government is at first founded on a contract, and that the most ancient rude combinations of mankind were formed entirely by that principle." And yet he adds, "in vain are we sent to seek for this charter of our liberties—it preceded the use of writing and all the other civilised arts of life." Consequently we cannot trace "government to its first origin," and therefore we cannot tell how government originated. But we do know, as Hume shows, that all governments of which we can trace the origin have been founded in some other way than by an original contract among all the members who are included in them. Hume further says, "that if the agreement by which savage men first associated and conjoined their force be meant (by the term Original Contract), this is acknowledged to be real; but being so ancient, and being obliterated by a thousand changes of government and princes, it cannot now be supposed to retain any authority. If we would say anything to the purpose, we must assert that every particular government which is lawful, and which imposes any duty of allegiance on the subject, was at first founded on consent and a voluntary compact." This is the real question. Those who found what they very incorrectly term "lawful government" on *an* original contract, must show us the contract. So far Hume's objection is good, and whether there was *an* original contract or not is immaterial. The question is, what was the origin of any particular government? Those who maintain that any particular government originated in a contract of all the persons who, at the time of the formation of the government, were included in it, cannot prove their case. Those who deny the original contract can show that many particular governments have originated "without any pretence of a fair consent or voluntary subjection of the people."

But an original contract, such as Hume admits, is as far removed from the possibility of proof as the origin of any particular government by virtue of a contract; nor have we any record of savage men associating to form a government. If one set of savage men did this, others would do it, and there must have been many original contracts, which contracts are the remote origin of all particular governments; but inasmuch as that origin of any particular government, which we do know, was not made by contract, and did not recognise the original contract, such government is unlawful, as those who contend for the theory of an original contract would affirm, or ought to affirm, if they would be consistent. Thus the practical consequences of the doctrine of an original contract, if we rigorously follow them out, are almost as mischievous as the doctrine that every particular government was founded on an original contract. It is true that the theory of an original contract of savage people being the foundation of government is a mere harmless absurdity, when at the same time we deny that any particular government has so originated, provided we admit that such particular government is not to be resisted simply because it is not founded on contract. Those who maintain that all existing governments rest on no other foundation than a contract, affirm that all men are still born equal—that they owe no allegiance to a power or government, unless they are bound by a promise—that they give up their natural liberty for some advantage—that the sovereign promises them these advantages, and if he fails in the execution, he has broken the articles of engagement, and has freed his subjects from all obligations to allegiance. "Such, according to these philosophers, is the foundation of authority in every government; and such is the right of resistance possessed by the subject" (Hume). This is a good exposition of the consequences that follow from the theory of every government being founded on contract.

Governments, as we now see them, exist in various forms, and they exist by virtue of their power to maintain themselves. This power may be mere force in the government and fear in the governed. Combined with the power of the government there may be the opinion of a majority in favour of the government, or of a number sufficiently large and united to control the rest; and this opinion may be founded either on the advantage which such number or majority conceive that they derive from the actual form of government, or the advantage which they and all the rest are supposed to derive from such government. The opinion of a considerable number may be strong enough to overthrow a government or to maintain it, but in either case it is not the opinion of all.

The real origin of government lies in the constitution of man's nature. Man is a social animal, and cannot exist out of society. He is of necessity born in a society, that is, a family, the smallest element to which we can reduce a state. He who requires not to live in a society, says Aristotle, must be a beast or a god. ('Politik.' i. 2). The nature of man compels him to seek union with the other sex. A man by himself is not a complete being: by the constitution of their nature man and woman must unite; and this is the foundation of a family. Those who accept the Mosaic account of the creation have there a clear statement of the origin of a family; and the father's authority is as much in accordance with the constitution of our nature as the union of the father and the mother. The various modes in which the descendants of a common pair might be detached from their primitive seats are infinite; and the modes in which they might be formed into political societies are infinite also. But if we have no account of them, it is useless to speculate what the precise modes may have been. Man, says Aristotle, is by nature a political animal; and by his nature he has an impulse to political union. He therefore follows the law of his nature by living in political society, as much as he obeys it by uniting himself with a woman. The form of any particular government, and the mode in which it may have been established, are the accidents, not the essentials, of political union, the real foundation of which is in our nature. But inasmuch as every community exists for some good end

(Aristotle), we estimate the value of any particular government by its fitness for this end, and the accidents of its form are subordinate to that for which pursuant to its nature it exists. Its origin may in many cases have been as obscure, and as little perceived, as the origin of those customs which exist in such endless variety in the world. Nobody supposes that customs originated in universal consent, or that people who follow them, or at least the majority who follow them, ever consider why they follow them. He who can trace the origin of customs can trace the origin of government.

The theory of men living in a state of nature and thence proceeding to form political societies, has apparently derived some countenance from the condition of many savages. There are perhaps people who may be said to have no government, if it be true that among some savages there is no bond of union except that of families. If this is so, each family is ruled by its head, like the families of the Cyclops (Aristotle, 'Politik.' i. 1), so long as the head can maintain his dominion. This state, if it exists anywhere, is perhaps what some people call a state of nature; but it is in fact a very imperfect state of nature, for the perfect state of nature is a political society, because it is that state to which the nature of our constitution impels us as the best. The savage in his lowest condition bears the same relation to the man who is a member of a political body, that the man who has not his senses bears to the man who has his full understanding. Both the savage and the idiot are imperfect men: they are the deviations from the course of nature.

SOCIETIES, ASSOCIATIONS. The great increase of Societies or Associations for all kinds of purposes is characteristic of the present condition of Europeans in Europe and of Europeans who have settled in other parts of the world. Association for particular objects is analogous to the great associations of political societies, but with this difference, that their object is something particular, and that they are really established and exist by the consent of the individuals who compose them.

Societies have been formed and exist for nearly every variety of object. There are societies for objects scientific and literary, sometimes called academies; for objects religious and moral; and for objects which are directly material, but in their results are generally beneficial to the whole of mankind. There are societies for objects which the members consider useful, but which other people consider to be mischievous. Generally, in this country, it may be stated that any number of individuals are permitted to contribute their money and their personal exertions for any object which is not expressly forbidden by some statute, or which would not be declared illegal by some court of justice, if the legality of such association came in question before it. The objects for which persons may and do associate are accordingly as numerous as the objects which individuals may design to accomplish, but cannot accomplish without uniting their efforts.

In some cases the State has aided in the formation of such associations, and has given them greater security for carrying their purposes into effect, as in the case of savings' banks and friendly societies. Sometimes the State grants a charter of incorporation to associations, which in many respects enables the body to transact its matters of business more conveniently. Sometimes the State perceives that it can extract some revenue from persons who associate for particular purposes, as in the case of fire-insurance offices, for all persons who insure their property in them (except farming stock, &c.) must pay the State 200 per cent. on the sum which they pay to secure their property against the accidents of fire. [Insurance, Fire.] If a man should think it prudent to invest a part of his annual savings in a life insurance, the State makes him pay a tax on the policy. A great many associations of individuals for benevolent, scientific, and such like purposes are left to direct their associations according to the common principles of law.

If lists were made of all the associations in Great Britain and Ireland, including those which are purely commercial, with an account of their objects, income, and applications of income, we should have the evidence of an amount of activity and combination that was never equalled before. How far it might be prudent to give to all associations for lawful purposes greater facilities for the management of their property and the making of contracts, subject to certain regulations as to registration of their rules and approval of their objects, is a matter well deserving of the attention of the legislature.

SOCINIANS. [Socinus, in Biog. Div.]

SODA. [Sodium.]

SODA-ASH. [Sodium.]

SODA, MANUFACTURE OF. [Sodium.]

SODA-WATER. [Aërated Waters.]

SODIUM. (Na, *natrium.*) The original name of natrium for this metal is derived from that of natron, nitron, or trona, old names of certain natural deposits of carbonate of soda which were long confounded with the true nitron or nitre (nitrate of potash). The term sodium originates from soda or sod-ash, the latter probably having allusion to the practice of burning the sods or turf of plants growing near the sea in order to obtain their ash, which is a crude carbonate of soda, known as *barilla.*

Sodium, like Potassium, was first isolated by Sir H. Davy. It may be prepared in a manner similar to, but with far greater facility than, the last-named element. Deville gives the following directions for obtaining it in large quantities. Intimately mix 717 parts of dried carbonate of soda with 175 parts of powdered charcoal and 108 of finely ground chalk; knead into a stiff paste with oil: heat in a covered iron pot till the oil is all decomposed; finally, distil, with the apparatus, arrangements, and precautions given under Potassium.

Sodium has the characteristic lustrous appearance of a metal, and is of a beautiful light rose colour. It may be obtained in quadratic octohedral crystals by the method described under Potassium. Like potassium, it speedily tarnishes by exposure to the air, owing to its great affinity for oxygen, and this occurs more rapidly when the air is moist; it requires for preservation the same precautions as have been mentioned with regard to potassium. It does not, like this metal, inflame when thrown upon water, but decomposes the latter with a hissing noise, the results being hydrogen and oxide of sodium, or soda, which, remaining in solution, exhibits the well-known alkaline character of that substance. When however it is placed on a moistened bad conductor of heat, as charcoal, it decomposes water with vivid combustion. Its specific gravity is 0.972. It is a good conductor of electricity and heat; but if too strongly heated in the air, it burns with a yellow flame.

The equivalent of sodium is 23.

Sodium combines with all the elementary gaseous bodies, two of which combinations, namely, those with oxygen and chlorine, are of great importance and utility.

Oxygen and sodium form two compounds, protoxide and peroxide of sodium; the former of these has been long known, and extensively used in various arts and manufactures. It was formerly called the *fossil* or *mineral alkali*, to distinguish it from potash, which, as being procured by the incineration of wood, was called the *vegetable alkali;* the peroxide has been discovered only since the metal was known.

Under the head of carbonate of soda we shall briefly mention the processes by which soda is procured for manufacturing purposes, stating merely at present that *protoxide of sodium*, or *anhydrous soda* (NaO) is prepared by heating the metal in dry oxygen gas. Thus obtained, it is a gray solid, resembling potash in appearance, but it is less fusible and volatile. It is extremely acrid to the taste, and is very caustic. It has great affinity for water, dissolving readily in it, and in large quantity, and the solution has strongly marked alkaline properties.

Sodium differs remarkably from potassium in some respects; thus, while both become first alkaline oxides, and afterwards carbonates, by exposure to the air, the carbonate of soda remains dry, while that of potash becomes fluid, owing to the absorption of water.

Sodium, as has already been noticed, is oxidised by decomposing water, and the solution of soda obtained, when evaporated to dryness, leaves *hydrate of soda* (NaO, HO). This is a solid white substance, greatly resembling soda in appearance and properties. It retains the water with such great affinity that it cannot be expelled by heat.

The hydrate is composed of one equivalent of soda and one equivalent of water.

Solution of hydrate of soda is largely used in the arts. It is made by boiling a tolerably strong solution of soda-ash or carbonate of soda with milk of lime until a portion of the filtrate ceases to effervesce on the addition of an acid. The strength of the solution is indicated by its specific gravity at 59° Fahr., as demonstrated in the following table by Zimmerman:—

Sp. gr.	Soda per cent.	Sp. gr.	Soda per cent.
1·4285	30·220	1·2392	15·110
1·4193	29·616	1·2280	14·506
1·4101	29·011	1·2176	13·901
1·4011	28·407	1·2058	13·297
1·3923	27·802	1·1948	12·692
1·3836	27·200	1·1841	12·088
1·3751	26·594	1·1734	11·484
1·3668	25·989	1·1630	10·879
1·3586	25·385	1·1528	10·275
1·3505	24·780	1·1428	9·670
1·3426	24·176	1·1330	9·066
1·3340	23·572	1·1233	8·462
1·3273	22·967	1·1137	7·857
1·3198	22·363	1·1042	7·253
1·3143	21·894	1·0948	6·648
1·3125	21·758	1·0855	6·044
1·3053	21·154	1·0764	5·440
1·2982	20·550	1·0675	4·835
1·2912	19·945	1·0587	4·231
1·2843	19·341	1·0500	3·626
1·2775	18·730	1·0414	3·022
1·2708	18·132	1·0330	2·418
1·2642	17·528	1·0246	1·813
1·2578	16·923	1·0163	1·209
1·2515	16·319	1·0081	0·604
1·2453	15·714	1·0040	0·302

Soda is met with in some mineral substances, but not so commonly as potash. It is found however in albite, or cleavlandite, a constituent of granite resembling felspar, except that it contains soda instead of potash. [Sodium, in Nat. Hist. Div.]

Peroxide of Sodium (NaO^3 ?).—This compound is formed on moderately heating sodium in oxygen gas. It burns vividly, evolving much light and heat; the peroxide resulting is of a yellowish-green colour. When put into water, it is decomposed, oxygen gas being evolved, and soda, or protoxide of sodium, remaining in solution.

It is not applied to any use, and, being decomposed by water, it does not form salts with acids.

Chlorine and sodium form only one compound, the important one, common salt, formerly called muriate of soda, and now *chloride of sodium* ($NaCl$). Of all natural soluble salts this occurs in the greatest quantity. It is met with solid, constituting *rock salt*, in solution in salt springs and in the ocean, and in small quantity in almost all spring and river water. [SALT TRADE; SODIUM, in NAT. HIST. DIV.]

This salt may be obtained artificially, either by the direct action of chlorine gas on sodium, or by saturating hydrochloric acid with soda; by evaporating the solution, common salt is obtained, which, in whatever manner or from whatever source procured, has, when pure, the following properties:—it is colourless, inodorous, has a purely saline taste unmixed with bitterness; is transparent, brittle, and easily reduced to powder; its specific gravity is about 2·125; when exposed to moist air, it deliquesces; it crystallises in cubes, which form under common circumstances is but little subject to modification. It is almost as soluble in cold water as in boiling. Water at 32° dissolves more than at 60°; 100 parts of water at 58° dissolve 36 of salt, and in a boiling saturated solution, the temperature of which is 229·5°, 100 parts of water hold 41·2 of salt in solution. A saturated boiling solution does not deposit crystals on cooling, evaporation being necessary to produce this effect; in pure alcohol it is insoluble. At a red heat common salt fuses, and on cooling it becomes a transparent brittle mass; the crystals contain no water of crystallisation, but decrepitate strongly when heated, owing to the expansion of mechanically interposed water. At a bright red heat it sublimes in the air, and tinges flame of a blue colour.

The uses of this salt have been known from the earliest ages. It is employed not only in seasoning food, but in preserving meat from putrefaction. It is used occasionally as a manure. In chemical manufactures it is employed for preparing hydrochloric acid, sulphate and carbonate of soda, and several other salts, and in the preparation of soap.

Sodium combines with fluorine, bromine, iodine, sulphur, phosphorus, &c.; the compounds which they form are unimportant, not being extensively applied to any useful purposes. Their formation is accomplished by methods similar to those employed in the preparation of the corresponding salts of POTASSIUM.

Salts of Oxide of Sodium, or Oxisalts of Soda.

It is perhaps scarcely requisite to state that these salts are never prepared by directly acting upon the metal sodium, although for purposes of curiosity they might all of them be so procured. The first which we shall notice is—

Nitrate of Soda (NaO, NO_5).—This salt may be prepared either by adding the metal, or soda, its oxide, to nitric acid; as a natural product it has, however, of late years been largely imported from Peru, where it forms a deposit similar to that of nitrate of potash in India. Nitrate of soda has a cooling saline taste, is inodorous and colourless; in a moist atmosphere it deliquesces; it readily crystallises, and the form of the crystal is an obtuse rhomboid; so obtuse indeed, and so near a cube, that the salt was originally called *cubic nitre*, to distinguish it from potash nitre, the crystals of which are prismatic. According to Gay-Lussac, 100 parts of water at 32° dissolve 73 parts of this salt; and at 212°, 173 parts: water at 60° dissolves half its weight. It is sometimes found with crude nitrate of potash.

Like nitrate of potash, it deflagrates with charcoal; but owing to its property of attracting moisture, it cannot be used in the manufacture of gunpowder. It is, however, used largely in making nitric acid, sulphuric acid, and as a manure.

There are three compounds of carbonic acid and soda; namely, 1, *carbonate*; 2, *sesqui-carbonate*; and 3, *bi-carbonate*.

1. *Carbonate of Soda* ($NaO, CO_2 + 10\,Aq.$).—This salt, formerly called *subcarbonate of soda*, was obtained from *barilla* or *kelp*: the former being the ashes of the *Salsola soda*, and prepared in Spain; the latter the ashes of burnt sea-weed, manufactured in Scotland. Since the duty has been taken off common salt, carbonate of soda is prepared, for the numerous uses to which it is applied, by first converting common salt into sulphate of soda by means of sulphuric acid, and then treating the sulphate, or *salt-cake*, as it is called, with small-coal and chalk in a reverberatory furnace; the result is a mixture of carbonate of soda and oxysulphide of calcium, termed *ball-soda*, or *black-ash*, when this is treated with cold water, the oxysulphide remains undissolved, while the carbonate of soda is taken up by the water, and by evaporation to dryness yields what is called *soda-ash*.

Carbonate of soda is a colourless, inodorous salt; it is devoid of smell, but has a disagreeable taste, though less so than carbonate of potash; it is readily soluble in water. The primary form of this substance, when crystallised by moderate evaporation of the solution, is an oblique rhombic prism. The crystals are frequently very large. They contain about 62 per cent. of water, the greater part of which they lose by exposure to the air, and efflorescing, fall to powder. At high temperatures the salt becomes fluid and boils. Water at 60° dissolves half its weight of carbonate of soda, and boiling water considerably more. The solution possesses the alkaline property of turning vegetable yellows brown. Like other carbonates, this salt is decomposed by the stronger acids, with effervescence of carbonic acid; and by lime, which separates its carbonic acid, it is rendered caustic.

The quantity of this salt prepared and used is enormous; it is required in making soap, and crown and plate glass, and for numerous other purposes.

2. *Sesqui-carbonate of Soda* ($2NaO, HO, 3CO_2 + 3Aq.$).—This compound is found native in Hungary, and also near Fezzan in Africa. By the natives it is called *Trona*. It is found in hard striated crystalline masses, is not altered by exposure to the air, and is readily soluble in water.

This salt appears to be formed when a solution of the carbonate of soda is heated with carbonate of ammonia, and probably also when a solution of the bi-carbonate is heated. Its taste is less alkaline than that of the carbonate, into which it is converted, when strongly heated, by losing one-third of its carbonic acid.

Bi-carbonate of Soda ($NaO, HO, 2CO_2$).—This salt may be formed by passing carbonic acid gas into a solution of the carbonate of soda; it is a crystalline granular compound. It is produced on the large scale by exposing crystals of carbonate of soda to a current of carbonic acid gas.

Bi-carbonate of soda has a very slightly alkaline taste, and acts very feebly on turmeric-paper. It requires about twelve times its weight of water for solution. When the solution is boiled, it loses one-fourth of its carbonic acid, and is converted into sesqui carbonate; at a red heat it loses all its water and half its carbonic acid, carbonate of soda resulting. It resembles the sesqui carbonate in giving no precipitate with the salts of magnesia till heated; and they both differ from the carbonate in this respect. It is used in medicine. *Soda water* is, or at least should be, a solution of bi-carbonate of soda in water charged with carbonic acid gas under pressure. [AËRATED WATERS.]

Sulphate of Soda ($NaO, SO_3 + 10Aq.$), formerly called *Glauber's salt*, may be formed by the direct combination of the acid and alkali; it is, however, generally prepared by decomposing common salt, as in the preparation of hydrochloric acid, or of carbonate of soda. It has also been met with in nature, but not largely. [SODIUM, in NAT. HIST. DIV.]

This salt is readily soluble in water, and the solution by evaporation yields colourless transparent prismatic crystals, the primary form of which is an oblique rhombic prism. It has a very bitter taste; effloresces when exposed to the air, by losing water of crystallisation. Boiling water dissolves its own weight of this salt, and water at 60° one-third of its weight. It is, however, most soluble at 93° Fahr.; at that temperature 100 parts of water will dissolve 50·6 parts of the salt. A boiling saturated solution of sulphate of soda may be cooled and kept for months without any crystals forming in it, provided that air be excluded; let, however, a crystal of the sulphate, or any solid matter, even a particle of dust, be dropped into the liquid, and the whole then shoots into crystals with considerable elevation of temperature. Sulphate of soda is insoluble in alcohol. When exposed to heat it first undergoes watery fusion, by melting in its water of crystallisation; when the water has been expelled, it becomes opaque white, and at a red heat it melts.

An *anhydrous sulphate* of soda, and a hydrate containing $NaO, SO_3 + 7Aq.$ may also be obtained. *Bisulphate of soda* contains $NaO, HO, 2SO_3$.

Sulphite of Soda ($NaO, SO_2 + 7Aq.$) is formed on passing sulphurous acid gas over carbonate of soda. It is used by paper manufacturers, under the name of *antichlor*, for removing the last trace of chlorine from their rag-pulp. *Bisulphite* of soda contains $NaO, HO, 2SO_2$.

Silicates of Soda. [SILICON; GLASS.]

Acetate of Soda. [ACETATE.]

Phosphoric Acid combines with soda to form several compounds. [PHOSPHORUS.]

Borate of Soda is a compound of boracic acid and soda. [BORON.]

For an account of numerous other salts of soda we must refer to chemical treatises; those whose properties we have detailed being merely the most useful.

General Properties of the Salts of Sodium.—Unlike the salts of potash, there is no acid nor any metallic oxide which forms a perfectly insoluble compound with the salts of soda, so that they cannot be precipitated in combination from solution. The best mode of distinguishing between these two alkalies is, by the yellow colour which soda salts communicate to the blow-pipe flame, salts of potash giving a violet tinge. They are separated from each other by taking advantage of the insolubility of the double chloride of platinum and potassium, and the great solubility of the corresponding sodium salt.

SODIUM, *Medical Properties of the Preparations of.* Sodium, when in the state of an oxide, is termed the mineral alkali, in contradistinction to potash, or the vegetable alkali.

Sodium possesses the ordinary qualities of a fixed alkali, but notwithstanding the resemblance it has to potash, the preparations, even with the same acid, present some differences which may be here pointed out.

In the oxidised state, or soda (pure or caustic), sodium is not employed in medicine to counteract acidity; nor in surgery to form an ulcer or to open abscesses, though for this latter purpose it possesses some advantages over hydrate of potash, inasmuch as it is not liable to spread or run.

It is only when in combination with carbonic acid that it is used to correct acidity. It exists in three states, namely, carbonate, sesquicarbonate, and bi-carbonate: the causticity of these is less in proportion to the increase of the acid. These preparations, administered in various ways, but chiefly in solution, are much used to counteract real or presumed acidity of the stomach. The abuse of the analogous preparations of potash has been already pointed out. [POTASSIUM.] The same caution is necessary as to soda-water, when that really contains any carbonate or bi-carbonate of soda, as it not unfrequently consists only of carbonic acid compressed into the water. The saline draughts so commonly employed in the medical practice of this country are liable to the same objection, and in all cases of debility, especially in the phosphatic diathesis, do infinite harm. For an opposite reason, they are extremely serviceable in all inflammatory complaints: the period when they should be discontinued can only be determined by an intelligent medical attendant.

The preparations of soda possessed of purgative properties are—the sulphate, or Glauber's salts, the phosphate, and the triple salt, called sodæ-potassio-tartras, or Rochelle salts, of which potash is also a constituent. Of these it is only necessary to observe that of the sulphate a much larger dose is required than of the corresponding salt of potash; and that the phosphate, being nearly tasteless, and extremely mild in its action, is a very proper aperient for delicate persons. A nearly similar character belongs to the Rochelle salt, but as this is decomposed in the stomach, it is as hurtful as the common saline draughts in cases of debility, though very beneficial in inflammatory disorders, particularly in both acute and chronic duodenitis. The same remark is applicable to the so-called Seidlitz powders formed with Rochelle salt and bi-carbonate of soda, to which, when dissolved, a solution of tartaric acid is added, and the mixture drank in the state of effervescence. The most quickly acting aperient is a Seidlitz powder dissolved in warm water; this is most proper at the commencement of common colds, influenza, and inflammatory diseases, but it should not be repeated without medical sanction, especially in influenza, where extreme debility speedily ensues.

The preparations of soda possessed of diuretic properties are the bi-borate and the acetate. The former of these has been already treated of [BORAX], and the second is rarely used, though, from not deliquescing, it has the advantage over acetate of potash, that it can be administered in the form of powder.

Chloride of sodium possesses purgative and emetic properties, which render it useful as a domestic remedy. Its other uses have been already pointed out. [BATHING; ANTHELMINTICS; FOOD.] Along with lemon juice it is a great means of checking sea-sickness.

Chloride or hypochlorite of soda is a powerful disinfecting agent. [ANTISEPTICS.] It is of great utility in the malignant sore throat of scarlatina, and in diphtheria.

Bisulphite of soda is a powerful antiseptic. It effectually checks or prevents fermentation. (Macculloch 'On Wine Making.') It retards the decomposition of animal substances, and for that purpose is used in Parisian dissecting-rooms.

Hypophosphite of soda is sometimes of use in the early stages of consumption; also in anæmia and chlorosis.

Valerianate of soda is a useful anti-spasmodic in some forms of indigestion, with spasms from unhealthy acids in the stomach.

SODIUM-ETHYL. [ORGANOMETALLIC BODIES.]

SOFTNESS is a condition of solid bodies in which the particles are held together by a cohesive power of small intensity: in consequence of this, such bodies change their figures upon the application of a small degree of force; and they do not recover their previous forms upon its removal.

This condition is the opposite of hardness, in which the particles are held together by a power of cohesion so great that they cannot be separated by any force which it may be convenient to apply to them. No body in nature is known to possess either of these qualities absolutely; but in contemplating the mechanical actions of soft bodies, balls of wet clay are generally used, while blocks of wood acting against one another in the directions of their fibres are frequently used to illustrate the effects of hardness. Balls of glass or ivory, or steel springs, serve to show the mechanical actions of elastic bodies. [COLLISION OR PERCUSSION OF BODIES.]

SOIL. Wherever the surface of the earth is not covered with water, or is not naked rock, there is a layer of earth, more or less mixed with the remains of animal and vegetable substances, in a state of decomposition, which is commonly called the *soil*.

The nature and composition of the soil, and consequently its greater or less aptitude to the growth and maturity of vegetable productions, depend on the composition, the proportion and the mechanical structure of the various substances of which it consists. When the soil is favourable to the chemical action by which the elements are combined to form vegetable substances, and admits that quantity of air and moisture without which this chemical action cannot take place in any given climate or temperature, vegetation goes on rapidly, and all the plants which are suited to the climate grow in the greatest perfection, and bear abundant fruits.

It is not however very frequently the case that a soil possesses all those qualities on which great fertility depends. So many circumstances must concur to make a soil highly fertile, that the great majority of soils can only be made to produce abundantly by being improved by art both in their texture and composition. Hence the practice and science of agriculture, which is founded on experience, but to which every progress in science also affords great assistance, by the additional light which every new discovery throws on the true theory of vegetation.

There are various modes of distinguishing soils, without entering into a minute analysis of their component parts. The simplest and most natural is to compare their texture, the size and form of the visible particles of which they are composed, and to trace the probable source of their original formation from the minerals which are found around or below them, or the rocks from which they may have been slowly separated by the action of the elements. The science of geology, which teaches the relative position and nature of the minerals of which the outer crust of the earth is formed, is consequently of the greatest utility in aiding us to compare different soils and in ascertaining their composition.

The knowledge which geology imparts is however not sufficient for the minuter classification of soils; for it is found by experience that the soils which lie over or near the different strata, as they appear near the surface, vary greatly, although they retain some general character which distinguishes them from others. The streams which descend from the hills, and flow towards the valleys, and through them to the sea, carry to a great distance the minuter portions of the minerals which they flow over in their course, while the larger and heavier are deposited much sooner. Hence the heterogeneous mixture of various earths and stones, and their stratification in thin layers, as is often found when a soil is examined which has never been disturbed by cultivation.

It is not sufficient to class soils according to the substance which predominates, as has been usually done, such as sandy, gravelly, chalky, or clay soils; for this gives very imperfect information respecting their nature or fertility; neither is it altogether sufficient to class them according to any particular geological formation.

The soils which have been evidently formed from the rocks which are supposed to be of secondary formation are fertile according to the proportion of the earths of these rocks which they contain.

Argillaceous earth exists in some proportion in almost every rock. It has the property, when mixed with other substances, as silica or lime, of fusing into a stone of great hardness and insolubility. In this state its effect on the soil is not to be distinguished from that of silica; and by burning common clay, or clay mixed with carbonate of lime, a sandy substance is produced resembling burnt brick, which tends greatly to improve the texture of those clays which contain little or no sand in their composition. It must be remembered that the stiffest clays contain a large portion of silica in an impalpable state; but this, instead of correcting their impermeable and plastic nature, rather adds to it. It is only palpable sand which with clay forms what is commonly called loam, and which, when the sand is in due proportion with a mixture of organic matter, forms the richest and most easily cultivated soils. Some of the rocks of secondary formations contain a considerable portion of alumina and lime; and when these earths meet with crystallised sand, a compound, or rather a mixture is formed, which has all the requisite qualities, as to texture, to produce the most fertile loams. The only deficiency is that of organic matter; but this is so readily accumulated wherever vegetation is established, or can be so easily added artificially, that these loams may always be looked upon as the most favourable soils for the usual agricultural operations; and if a considerable depth of loam is found, which neither retains water too long nor allows it to percolate too rapidly, it may be looked upon as a soil eminently capable of the highest degree of cultivation, and on which no judicious outlay of labour will ever cause loss or disappointment to the farmer.

Thus, the greensand which lies under the chalk, and appears near the surface in several parts of Britain, consists of silicious, argillaceous, and calcareous earth, intimately combined and in a high state of subdivision, and yet not forming a compact paste with water so as to dry in hard lumps, but having rather the loose appearance and granulation of fine sand, whence its name. On this soil are found the finest wheats; but such is the variety of its form as it approaches towards the chalk or crystallised sand, or the plastic clay, that the soils which it forms have every degree of texture, from loose sands to stiff marls, whose chief use is to mix with other soils and improve them. In general however it may be said that the soils of which the greensand forms a considerable part are productive and easily cultivated, and that they repay the labour and manure expended on them better than most others. A narrow strip of this sand crosses Bedfordshire, and in the neighbourhood of Sandy and Biggleswade are raised some of the finest culinary vegetables which come to the London market. This sand, though light in appearance, and very easily worked, contains much of the impalpable substance mentioned before; and this, with careful cultivation and manuring, makes it peculiarly suited for gardens as well as for corn-fields. In its natural state it is easily distinguished from other sands by certain dark particles in it, which give it the greenish hue from whence it has been called greensand, and also by its effervescence with strong vinegar or any other acid.

Chalk is perhaps the mineral most widely spread throughout Britain. The chalk formation of itself forms a very poor and barren soil. In the course of ages the surface of the chalk has been covered with a thin coating of soil, consisting of chalk and organic matter chiefly. On this soil the finest and most aromatic plants are found, but of small dimensions, affording a sweet short pasture, much relished by sheep. The constant treading in of the dung of the sheep, and the stimulating effect of their urine, gradually increase the quantity of vegetable and animal matter; and thus the turf becomes close and rich: but if this thin coat be disturbed by the plough and mixed with the chalk below, it will, after one or two tolerable crops of corn, be reduced to its original sterility; and it requires ages to restore the fine pasture which once covered it. Such is the case with those hills which are called the South Down Hills, in Sussex and Wiltshire, on which are bred the excellent sheep which bear that name.

But the chalk has in many places been carried down by the rains and transported in a comminuted state to the sandy or clayey valleys around them, and by the mixture has greatly improved both, forming various loams and marls in themselves highly fertile, or very useful in increasing the fertility and texture of other soils. Chalk has the peculiar property of neutralising acids of every description, and of preventing their formation in the soil by the fermentation of vegetable substances; while it assists in that slow decomposition which causes the evolution of carbonic acid, and thereby assists and invigorates vegetation. The presence of carbonate of lime, if it does not exceed a third part, and if it is intimately blended with alumina and silica, is always a sign of fertility, especially when loose sand is mixed with it, so as to form one-half of the whole soil. This is called a light calcareous loam, and is usually found on the slopes or around the base of chalky hills.

The Weald clay consists of very minute particles of alumina and silica, forming a tough unctuous earth, fit for the growth of oaks, with very few stones or visible particles. This soil is found in Sussex and Kent chiefly. The plough cuts it into continuous slices, when it can be ploughed, which is only in a certain state of moisture; for when it is dry the surface is as hard as a rock, while the subsoil is continually moist, the water being unable to pass through its pores. It has the most unpromising aspect, drying into hard lumps like brick, and apparently incapable of being brought to such a state of mellowness as to admit the seed or cause it to vegetate; yet this stubborn soil may be rendered fertile by tillage, draining, and exposure to frost in winter; and its tenacity may be corrected by the application of lime, ashes, and other substances, especially fresh stable-dung, which interpose and prevent the clods from re-uniting into one tough impervious mass. Lime and chalk do this most effectually; and when the weald clay has been brought to a looser texture, it produces beans, wheat, oats, and clover in great perfection.

The system of complete under-draining by parallel drains, at the distance of from 10 to 20 feet, which carries the moisture into the surrounding ditches, has in many instances so greatly improved the weald clays, that those who had formerly attempted to cultivate them can scarcely believe their eyes when they see the abundant crops produced. Subsoil ploughing has also done wonders after complete draining, in some cases rendering the soil so mellow and loose as to allow of the cultivation of turnips, especially the Swedish. As clay soils predominate in England, and their improvement has been almost despaired of, it is of great importance that it should be generally known that no soils repay the cost of improvement better than clays, provided the surface be such as to admit of perfect draining.

Another clay is called the Oxford clay. This is of a bluish colour, which alters on exposure to the air, probably from a change in the oxidation of the iron which it contains. This clay is favourable to the growth of grass, and some of the richest pastures in Wiltshire and Oxfordshire have it for a subsoil, over which the decomposition of the roots and leaves of the grasses has formed a layer of vegetable mould of the highest degree of fertility. In the fens of Lincolnshire, the Oxford clay is covered by a coat of peat, formed by the decomposition of aquatic plants, which have accumulated wherever the water had no natural exit. When these fens were laid dry by an extensive system of draining, the peat was converted into a rich soil by the admixture of the clay which was found under it.

The *Oolite* formation contains much carbonate of lime, cemented by an unctuous earth into various sorts of stone. The soil which lies over them, and which is of nearly the same nature, but broken and disunited, is various in its qualities. Sometimes it is of great fertility, and sometimes nearly barren, according as the impalpable matter in it abounds and contains a due proportion of the different earths, or it resembles a loose chalky sand, in which moisture is retained with difficulty. In the first case, it produces every kind of grain in abundance with moderate cultivation; in the latter, it requires a great outlay of manure, which readily disappears, and then it is justly called a poor hungry soil.

On the red-sandstone is found a soil which is usually of the finest quality. The fine loose soils of Devonshire and Somersetshire are of this description. It unites most of the requisites of a good soil, both in its texture, neither too close nor too loose, and in the impalpable matter in its composition. It is peculiarly adapted to the growth of potatoes and all roots which form the basis of a judicious cultivation. When it contains a proper portion of calcareous earth, it may be reckoned amongst the most fertile soils; and where this is deficient, the addition of lime or chalk is the best means of improving it. The calcareous earth seems greatly to add to the effect of the usual manures, so that a much smaller portion is required to produce good crops.

Each distinct formation gives rise to a great variety with respect to fertility, even where the basis remains the same: but it is of great importance to the farmer to ascertain the general nature of the rocks and strata on which his farm is incumbent.

The alluvial soils formed by the deposit of a variety of earths in a state of great division, and mixed with a considerable portion of organic matter, form by far the most productive lands. They will bear crop after crop with little or no addition of manure, and with a very slight cultivation. These soils are found along the course of rivers which traverse extensive plains, and which have such a current as to keep very fine earth suspended by a gentle but constant agitation, but not sufficiently rapid to carry along with it coarse gravel or sand. Wherever there is an obstruction to the current and an eddy is formed, there the soil is deposited in the form of mud, and gradually accumulating, forms those alluvial soils which are so remarkable for their fertility when carefully protected from the inroads of the waters. In these soils the impalpable matter greatly predominates; but the intimate mixture of the earths with organic matter prevents their consolidating into a stiff clay; and the gases which are continually evolved from the organic matter keep the pores open, and give scope to the growth as well as the nourishment of the roots. It is in the alluvial soils principally that an accurate analysis is useful; because the proportion of their constituent parts varies in innumerable degrees. It may be laid down as a general rule, that the most fertile of these soils are those in which the earths are nearly in equal proportions, silica, however, being the most abundant, with about 10 per cent. of organic matter; a greater proportion of this last would form too loose and spongy a soil to bear good crops of corn, especially of wheat. But 4 per cent. of vegetable matter, with a good mixture of earths, and some phosphate of lime from the decomposition of bones and marine shells, produces a very good wheat soil. The rich warp-lands along the Humber are artificial alluvial soils, and although they contain but a small proportion of organic matter, are highly fertile after their first deposition, but it is observed that they gradually become more tenacious and difficult of cultivation as this humus is carried off by the crops; and that it is soon necessary to add animal and vegetable manures to supply its deficiency.

Organic matter is no doubt essential to great fertility in a soil, but some soils require more of it than others. In every stage of its spontaneous decomposition it keeps the pores of the soil open, and admits, if it does not even attract, air and moisture to the fibres of the roots. In all rich soils which have been long cultivated, especially in gardens, there are particles of a dark colour and fibrous texture, which in the microscope appear like minute logs of charred wood. These keep the soil open, and supply carbonic acid, when the air reaches them. A proper texture seems an indispensable condition of fertility. It is much easier to supply the deficiency of vegetable matter in a soil, which at best forms but a very small portion of it, than of silica or clay, which should enter into its composition in the proportion of one half or a third of the whole. It is practicable to carry lime or chalk upon soils which do not contain calcareous matter; clay may also be carried upon loose sandy soils, where it can be found below the surface, or at a moderate distance; but if a soil is very deficient in silica, it requires so large a proportion of this earth to give porosity to stiff clay, that it very seldom can repay the trouble and expense. Hence the difficulty of bringing poor wet clay soils into a fertile state, except where an abundance of chalk and vegetable manures can be easily procured. In this case the perfect draining of the land, and exposure of the ploughed surface to the frosts of winter, with the addition of chalk and manure, produce such an alteration in the texture of the clay, that by continuing the improving process it is entirely changed into a mellow and fertile loam. The burning of a portion of the retentive subsoil into a brick-like earth gives it a porosity which renders it mechanically similar to silicious sand, and converting the iron which all these clays contain into a peroxide, the soil is thereby greatly improved in fertility; for it seems that iron, in a state of slight oxidation, or combined with any acid, is hurtful to vegetation, whereas the red peroxide is not only innocuous, but seems to have fertilising properties.

In ascertaining the value of a soil for the purposes of agriculture, two circumstances should be carefully noticed. The first is the permeability of the soil to water; and the second is its power of absorbing moisture from the atmosphere. To ascertain the first, it is only required to place an equal weight of different soils in glass tubes of equal diameter, pressing them so that they shall occupy equal spaces, but not filling the tubes. Then pour an equal quantity of water over each soil, and place them upright with cups under them. Examine which has the surface first dry, and how much water runs through each in a given time. That which presents a dry surface, while it holds most water in its pores, is probably the best. To ascertain the comparative absorption of moisture, the soils are dried in pairs on a plate of metal heated by steam, or at a heat of 212°, to expel the water. They are then placed in equal quantities in similar flat cups or dishes, and placed in opposite scales of a balance, and poised. The apparatus is exposed to a moist atmosphere out of doors, or in a cellar, and occasionally examined. That which is heaviest is, in general, the most fertile.

It is often useful to ascertain roughly the composition of a soil, without having time or opportunity to make accurate experiments. A graduated glass tube, which can be carried in the pocket, and a small phial with a ground stopper, containing diluted muriatic acid, and secured in a wooden case for fear of accident, is all the apparatus required. A little of the soil is taken and moistened with water; a few drops of the acid are poured on; and by the greater or less disengagement of bubbles the proportion of calcareous matter is guessed at, and its presence proved. The soil mixed with water is poured into the glass tube and well shaken. In a few minutes the coarse sand is deposited: shortly after the finer sand, and, lastly, the clay and impalpable matter, of which the lightest remains longest suspended. Distinct rings can be observed in the deposits, and the graduated tube shows their proportion. A person accustomed to this method will guess with great precision the general qualities of the soil; and when the geological structure of the neighbourhood and the nature of the subsoil are taken into consideration, the value of the land for pasture or cultivation is guessed with little danger of making very glaring mistakes. To surveyors and valuers this method is of very great help, when other means are not at hand. Among the properties of soils of the greatest agricultural importance must be named the absorptive powers which they possess over ammoniacal and other valuable ingredients of manures, either volatile or soluble, which would otherwise be wasted when applied to the land. This fact, first observed by Mr. Thompson, M.P., has since been investigated by Professor Way, and explains the economy of autumnal manurings and top-dressings in the winter season, when vegetation is inactive and unable at once to turn to account artificial stores of food for plants.

In practice, soils are usually divided into light, mellow, and stiff; but this gives very little information, there being every imaginable variety in each of these. There are still minute circumstances which produce great fertility or the reverse, and which it is difficult to investigate. An accurate chemical analysis, which, however, is a process requiring the service of the educated chemist, joined to a careful mechanical examination, and very correct accounts of the average produce under different systems of cultivation, can alone give us a scale according to which the natural fertility of different soils can be classed; and this must be the work of time and industry joined to science and practical knowledge. Directed as it is to the detection and estimation of ingredients, many of which occur in very small proportion, the process of chemical analysis is one which cannot be undertaken by the farmer. It is sometimes useful to him, however, to know the exact composition of his soil, and the chemist is thus sometimes able to point out the causes of infertility, and so enable him to remove them. When, therefore, he is at a loss, such an analysis may be the guide he needs; and in a deficiency of phosphate of lime, or an excess of chloride of sodium, or a deficiency of organic matter, or in the presence of iron salt which is thus detected, he may read the cause of his failure, and so be able to remove it.

SOILING is the name given in agriculture to the mode of feeding horses and cattle in the stable or yards with food brought to them as it is cut in the meadows or fields. The great advantage of soiling cattle is the increase of manure of the best quality, which is thereby produced; and this circumstance alone can counterbalance the great trouble and expense incurred in cutting and carrying all the green food from a distance to the farmyard.

The system of soiling is not very generally adopted in British husbandry, it being so much easier to allow the cattle to crop their food in the pastures; but in those countries where property in land is greatly subdivided, and where farms are small and good pastures scarce, as in Flanders, France, and Switzerland, especially where the vineyards render manure scarce and dear by taking a considerable portion of it and returning none, there the soiling of cattle is almost a matter of necessity. A cow or ox requires from two to three acres of pasture or meadow to feed it all the year round, allowing a portion for hay. But by raising clover, lucern, sainfoin, tares, and other green crops, one or two cows can be fed with the produce of one acre, especially if a portion is in mangold wurzel or other succulent roots. Thus the straw of the white crops is converted into excellent manure, and the land kept in a state of fertility.

In proportion as a farm is larger in extent, so the expense of soiling increases, both from the distance of the fields where the green crops grow, and from the same distance to which the dung has to be carted. There is a limit therefore to the soiling system, unless there be many yards or stables in different parts of a farm, so as to subdivide it, and make each yard the centre of a distinct system of soiling, with fields near at hand for the green crops. In almost every experiment on a large scale it has been found that soiling was only a certain mode of purchasing dung, and that it often was more expensive to procure it in this way than to send to a considerable distance to purchase it in towns. Where it cannot be purchased at all, there are no other means, in many situations, of producing a sufficient quantity; and the trouble and expense of soiling must be submitted to. In almost every case where sheep can be folded to feed off the crops, the soiling of cattle is a loss, because the sheep pay something for their food; the cattle in the stall do so less frequently.

But there are animals which must be fed for the work of the farm, such as horses or oxen; and these are much more profitably and economically fed by soiling than by any other means. A horse or ox, if he works eight or ten hours, has no time for rest if he has to crop his food from a short pasture, however sweet; whereas an abundant supply of clover, lucern, or tares enables him to take a hearty meal and lie down to rest. He wants no corn with this food, and does his work without losing flesh or activity.

There is nothing easier in a mild climate, and especially a moist one, like Britain or Ireland, than to have a succession of green food from the beginning of spring to the end of autumn, and afterwards a succession of succulent vegetable food through the winter. Rye and winter barley, sown early in autumn, will be ready to cut as soon as the mild weather of spring commences; some sown later with winter tares, and the young clover, which has not been cropped in autumn, will succeed. After this come artificial grasses, as Italian rye-grass and the grass of water-meadows mown early; although this last is not such hearty food for working cattle; but when joined to a mixture of oats and cut straw, their watery nature is corrected. Clover and spring tares (when these last are sown at proper intervals), lucern and sainfoin (if the soil is suited to them), will afford a constant and abundant supply to the scythe which cuts the daily allowance. It is prudent to provide against failure, and have more land in these crops than is absolutely necessary, because the surplus can always be made into hay or reserved to ripen its seed; and these green crops, valuable as they are, far from deteriorating the soil, clear it of weeds, and render it more fit to bear corn afterwards. Turnips, carrots, and mangold wurzel provide with hay and straw the winter food. And by steaming the roots or pulping them, and so mixing with chaff of hay or straw, a palatable and nutritious food may be provided at small expense. In these cases soiling is profitable and economical.

It is generally thought in those countries where the soiling system is most universally adopted, that it is best to allow the green food to remain twelve or twenty-four hours after it is cut, before it is given to cattle. This may be prudent with cows and oxen, which are apt to eat voraciously, and are subject to be hoven from the fermentation of the green food in the paunch or rumen: but, excepting in the case of young vetches, which are more physic than food, for horses there is little danger; and if the food is not wet with dew or rain, the fresher it is eaten the better it will nourish the animal, and the more he will relish it.

If any one is desirous of calculating the expense of soiling any number of beasts, he has only to reckon what time of men and horses it will take to cut the food and carry it to the cattle, from the average distance of the fields in which it can be raised in succession. Much of their time is lost in the morning and evening in going backwards and forwards from the field to the yard; for there can scarcely be an establishment so large as to keep them employed a whole day; and if there were, the fields must be so large and so distant, as to greatly increase the expense of carriage. Not to enter into minute calculations, it is fully proved, that, to a certain extent, soiling is profitable and economical, when it can be done before and after the usual hours of labour; but that when undertaken on a large scale in any one locality, it is usually attended with loss, the manure produced being purchased at too great a price.

If a labourer who has an allotment of half an acre of good light land would devote it entirely to raise food for a cow, his wife and children cutting the food and tending the cow in a small yard with a shed, or in an airy cow-stall, he would find that he had a much greater clear profit, than if he had sown his land every year with wheat, and had always a good crop, which last supposition is improbable. There would be no better stimulus to industry than to let a piece of land for this purpose to every man who could purchase a cow and feed it by soiling.

SOL, in music, the name given, in sol-fa-ing, by the English, Italians, and French to the fifth of the scale; and by the two last also to the sound called G by the Germans and English. [SOLMISATION.]

SOLANINE, a vegetable alkaloid obtained by Desfosses from the berries of the *solanum nigrum*, and the fruit of the common potato.

In appearance solanine resembles sulphate of quinine, but the crystals are finer and shorter; it restores the blue colour of litmus when reddened by an acid; dissolves in acids, and is precipitated from them by the alkalies. The hydrochlorate and acetate of solanine have a gummy appearance when evaporated to dryness, but the sulphate and phosphate are crystallisable. It is extremely poisonous: a grain of it, dissolved in dilute sulphuric acid, killed a rabbit in six hours. The analyses which have been made of this alkaloid do not accord. The following are the numbers obtained by Blanchet and O. Henry respectively.

	Blanchet.	O. Henry.
Hydrogen	8·9	9·14
Carbon	62·0	75·00
Oxygen	27·5	12·78
Azote	1·6	3·08
	100·0	100·00

SOLA'NUM DULCAMA'RA, an indigenous perennial climbing plant, common in wet and shady places, especially hedges. It has a remarkably zigzag stem, with alternate leaves, the lower ones lanceolate, entire, the upper hastate; the flowers resemble those of the potato, but are smaller, and are succeeded by a cluster of red berries. This plant is called *woody* nightshade, to distinguish it from the *Atropa belladonna*, or *deadly* nightshade. The young twigs or tops are officinal, and they should be gathered in spring, before the flowering of the plant, or in autumn while the leaves are yet *fresh*, as much activity seems to belong to the leaves, and the twigs are best from plants about three years old. When fresh, the plant has an unpleasant odour, which is in a great measure lost by drying, as is also a large portion of water. The taste is at first bitter and slightly acrid, then sweet; hence the name *bitter-sweet* given to it.

Ten pounds of the dried twigs yield two pounds of extract. According to Pfaff, 100 pounds of perfectly dried stems yield a bitter-sweet extractive (picroglycion), 21; vegeto-animal matter, 3; gummy extractive, 12; gluten with wax, 1; resin with benzoic acid, 2; gum, starch, salts (chiefly of lime), 6; and woody fibre, 62. Solanina (solania) has been found by Desfosses. Whether picroglycion, called also dulcamarin, and dulcarin, is a distinct principle, or a combination of solanina with sugar, is doubtful.

Bitter-sweet, when taken fresh, has a slightly narcotic influence, causing also nausea, vertigo, and a dryness of throat, like other solanaceous poisons. If delirium display itself, it is always of a most frantic kind. Perspiration or an increased discharge of urine generally occurs, followed by gentle purging.

Bitter-sweet is chiefly employed in cutaneous diseases, especially of the scaly kind, such as lepra; it may be given internally, while a strong wash of it is applied externally. It is also useful in some vesicular diseases, such as herpes and eczema. In these its virtues as an external application may be increased by dissolving in it sulphuret of potass. This combination relieves most effectually the intolerable irritation of these complaints.

It is usually ordered in the form of decoction, but long boiling is destructive of its powers. Slow simmering is preferable. The extract, when prepared from the fresh plant with a low degree of heat, is a good form for internal administration, as it may be combined with antimonials.

In cases of poisoning by the berries, often mistaken for currants, the stomach-pump should be used as speedily as possible, and moderate venesection is of service.

SOLAR CYCLE. [PERIODS OF REVOLUTION.]

SOLAR ECLIPSE. The phenomena of an eclipse of the sun resemble those of the moon in one respect only, namely, that the body of the luminary disappears. In all other respects there is so great a difference, both in the cause of the phenomenon and its attendant circumstances, that it is a pity one term, eclipse, should be used in senses so different. In the first place, the disappearance of the moon arises from the earth intercepting the light which she ought to receive, while that of the sun is the consequence of the moon coming between the sun and the earth. The body of the moon is never absolutely hidden, and is even slightly visible through a telescope during the darkest eclipse: but the body of the sun is really hidden by the intervention of the opaque substance of the moon. Again, the phenomena of an eclipse of the moon are the same for every point of the earth at which they are visible: the beginning, middle, and end of the phenomenon happen at the same instant of absolute time everywhere, and the same portion of the moon is hidden from all the earth at the same instant. But in a solar eclipse, it entirely depends upon the position of the spectator whether there is any eclipse at all; and of two persons at different parts of the earth, at the same instant, one may see the sun totally eclipsed, while the other may, by the brightness of the sun's rays, not know that the moon is almost close to him. A screen held before a candle may be an eclipse of the candle for one person in the room, but not for another, on account of their difference of place; this is an illustration of the solar eclipse: a ball thrown into a dark corner may be invisible to all the persons in a room at the same time; this is the same illustration of a lunar eclipse.

If the earth had no motion of rotation, the inhabitants of any one place would see something exactly resembling a lunar eclipse; the sun being in place of the moon, and the moon in place of the earth's shadow. But different places would see different kinds of eclipses, some losing more of the sun's body, and others less. The rotation of the earth, without materially altering the character of the phenomenon, makes it much more difficult to calculate: for it is as if each spot of the earth, instead of standing still to witness one phenomenon, or one simple eclipse, were constantly taking into view portions of different phenomena, a part of one followed by a subsequent part of another. In an eclipse of the moon, whatever may be the phase for the time being, from the disappearance of the first to the reappearance of the last edge, the only question as to whether such phase will be visible or not at any place is the following:—Will the moon be above the horizon at that place when the phase occurs? Suppose, for instance, it were asked, what places on the earth will see the beginning of the eclipse, the disappearance of one edge of the moon, at the instant when the moon rises? The answer is, calculate the absolute instant of the beginning of the eclipse, find out the spot to which the moon is vertical at that instant, and all places 90° distant from it will be exactly in the same predicament with respect to the eclipse. But in an eclipse of the sun, the beginning at two different places does not happen at the same instant; the inhabitants of any the same circle see very different phases, and a line drawn through all the places which see the same sort of phase under the same position of the luminaries with respect to their horizons, will be very different from a circle. Without attempting to give any account of the modes of ascertaining all these points, we subjoin, from the 'Nautical Almanac,' a projection of the eclipse which took place on the 7th of July, 1842.

The southern line passes through all the places which see a simple contact of the luminaries and nothing more: the edges of the luminaries unite for a moment and then separate. This line touches the two ends of a large figure of eight divided by another line passing through its loop; and the portion of the earth which at any time sees a total eclipse is contained in the broad shaded band. On the line marked "beginning of eclipse at sunrise" live those to whom the luminaries rise in contact: the other lines are similarly explained. The eclipse is first seen at the place marked "First contact" on the line just mentioned. One point is marked as having both beginning, middle, and end of the eclipse at sunrise: this means that the eclipse is there only a contact, so that its beginning, middle, and end take place at the same moment, and that moment is sunrise. At the loop of the figure of eight, the beginning, middle, and end are represented as each of them taking place both at sunrise and sunset: which must be a mystery to those who are not used to trace mathematical conceptions to their limits: are there two eclipses, one for sunrise and one for sunset? The explanation is this: there is at every moment of time a point in the arctic regions at which the sun is making its first appearance or its last appearance previously or subsequent to the long polar day or night. As this moment approaches the days shorten, if the disappearance be coming on, and begin from nothing if the appearance be coming on: the long day or night being preceded by the ordinary days or nights of the rest of the earth. Now the point which is at the loop is that point of the earth at which the sun and moon are in contact (without any further eclipse) at the moment when the sun first grazes their horizon after their polar night: so that their day is but a moment, and at that moment the contact takes place.

The figure of the projection is not always like that of the preceding: sometimes the loops become two ovals separated by a line which is continued through the middle of them, the part of this line between the ovals being a line on which nothing but a simple contact is seen.

There is an excellent mathematical account of eclipses in general, with the full mode of calculating them, and examples, by Mr. Woolhouse, in the Supplement to the 'Nautical Almanac' for 1836. From this we extract the summary of the limits within which an eclipse, whether of the sun or moon, can happen.

At the time of full moon an eclipse of the moon will be certain when the moon's latitude is less than $51' \, 57''$, impossible when it is greater than $63' \, 45''$, and doubtful between these limits. For the doubtful cases an eclipse will result when the moon's latitude is less than

$$\frac{61}{60}(p + \pi - \sigma) + s + 16''$$

p and s being the equatorial horizontal parallax and semi-diameter of the moon, and π and σ those of the sun.

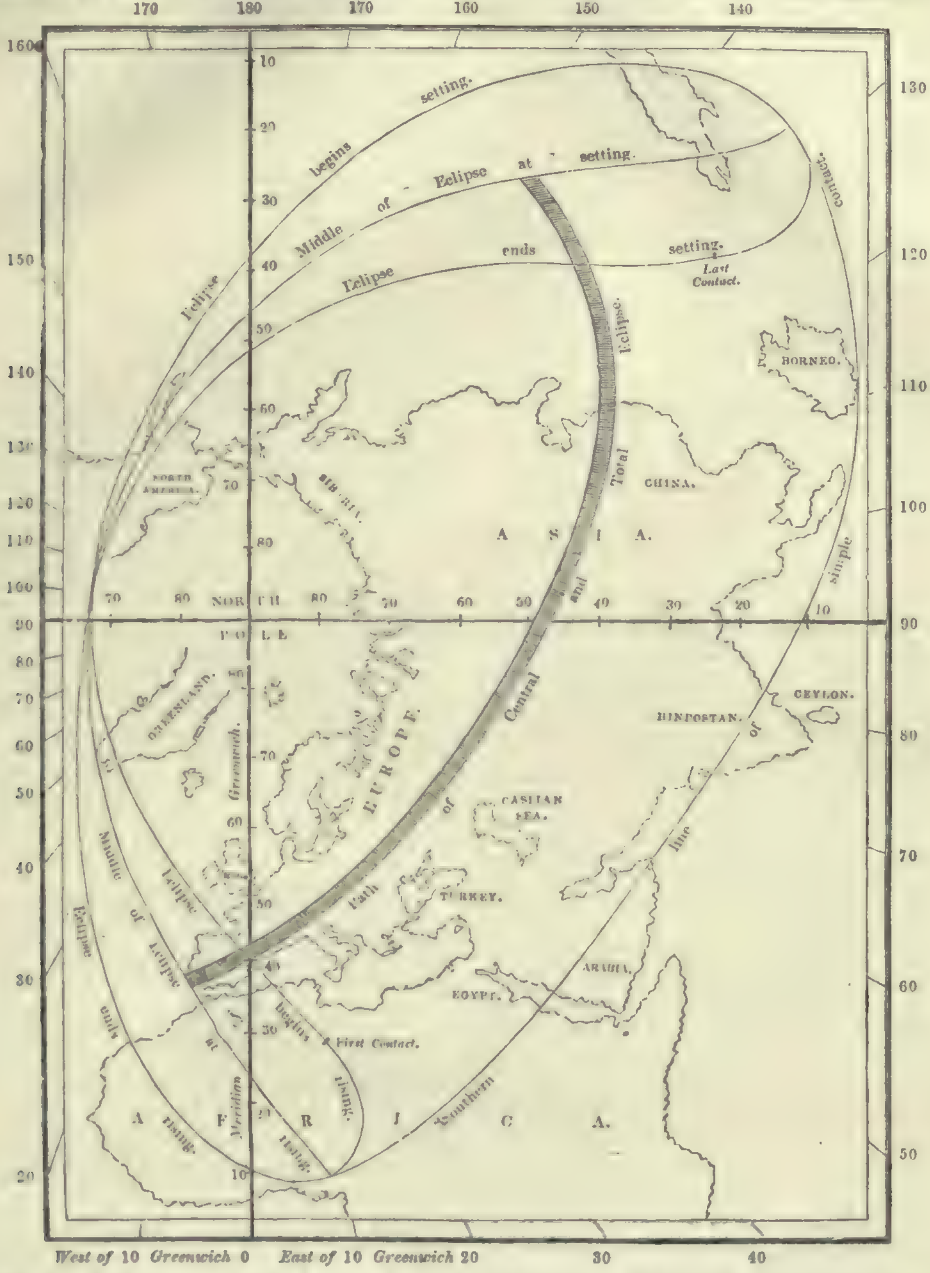
At the time of new moon an eclipse of the sun will be certain when the moon's latitude is less than $1^\circ \, 23' \, 15''$, impossible when it is greater than $1^\circ \, 34' \, 52''$, and doubtful between these limits. For the doubtful cases, an eclipse will happen when the moon's latitude is less than

$$p - \pi + \sigma + s + 25''.$$

It is hardly necessary to state that eclipses of the sun are frequently wholly partial, that is, not total for any one moment to any one part of the earth. Sometimes, though the eclipse be central, it is not total on account of the moon not being near enough to hide the whole of the sun; in which case part of the latter is seen as a bright ring round the part hidden by the moon, and the eclipse is called annular.

Before proceeding to give some account of the physical phenomena observed during total eclipses of the sun, it may be desirable to allude briefly to some of the more interesting eclipses of this nature recorded in history.

The ancient literature of Greece and Rome contains several incidental allusions to the occurrence of total eclipses of the sun. The most celebrated of these is the eclipse mentioned by Herodotus as having taken place during a battle between the Medes and Lydians. The historian relates that the two hostile armies were so much terrified by the spectacle of the eclipse, that they suddenly desisted from fighting, and concluded a treaty of amity and peace. He further states that the eclipse had been foretold to the Ionians by Thales the Milesian. The precise date of this eclipse has given rise to much discussion in modern times. In 1811 the late Francis Baily communicated a paper to the Royal Society, in which, by availing himself of Bürg's lunar tables, he endeavours to prove that a total eclipse of the sun which occurred on the 30th of September, 610 B.C., must have been the one alluded to by Herodotus. He acknowledges, however, that the elements of the lunar orbit employed in his investigation failed to account also for a total eclipse of the sun which Diodorus Siculus mentions as having occurred while Agathocles, king of Syracuse, was proceeding with his fleet to Africa. In a paper published in the 'Philosophical Transactions of the Royal Society' for 1852, Mr. Airy has taken up the subject of this eclipse. His researches are based upon a new determination of the elements of the lunar orbit derived from the Greenwich observations, and the values of the secular acceleration of the mean motion and node assigned by Professor Hansen. The conclusion at which he arrives is, that the eclipse referred to by Herodotus must have occurred on the 7th of September, 585 B.C. He shows that this date accords satisfactorily with the eclipse of Agathocles, and also with an eclipse briefly alluded to by Xenophon as having occurred at Larissa, in Asia, during the retreat of the ten thousand Greeks.



Path of the Moon's Shadow and Penumbra over the Surface of the Earth during the total Solar Eclipse of July 7, 1842.

Plutarch, in his 'Dissertation on the Lunar Spots,' makes a brief but interesting allusion to a total eclipse of the sun which happened in his time. He mentions that it occurred about midday, that the darkness was so great as to cause the day to resemble night, and that stars were everywhere visible. Kepler, who investigated the probable time of the occurrence of this eclipse, is of opinion that it is identical with an eclipse which happened in the year 113 A.D.

The records of modern history contain a variety of interesting allusions to the occurrence of total eclipses of the sun.

Halley, in a paper on the total eclipse of the sun which happened at London in the year 1715, mentions, as an illustration of the rarity of such phenomena, that no previous eclipse of the same nature had been visible in the metropolis since the year 1140. This eclipse is recorded in the Saxon Chronicle; a brief mention of it is also made by William of Malmesbury. In the Saxon Chronicle it is stated that, "in the Lent, the sun and the day darkened about the noontide of the day, when men were eating, and they did light their candles to eat by. That was the thirteenth day before the Calends of April. Men were very much struck with wonder." William of Malmesbury states, "that while persons were sitting at their meals, the darkness became so great that they feared the ancient chaos was about to return; and upon going out immediately, they perceived several stars about the sun."

Total eclipses of the sun are mentioned in history as having occurred in the years 1187, 1241, 1415, 1433, 1485, 1506, 1530, 1544, 1560, 1567, 1598, 1605, 1652, and 1699. The eclipses of 1433, 1598, and 1652 were visible in the British Isles. The eclipse of 1433 occurred in Scotland. According to Maclaurin, there is a manuscript account of it preserved in the library of the Edinburgh University. The moon's shadow on the occasion of the eclipse of 1598 appears to have passed over the border counties of England and Scotland. The day of its occurrence, which was Saturday, was long remembered in both countries as Black Saturday. The eclipse of 1562 was visible in the north of Ireland and in Scotland.

In 1706 there occurred a total eclipse of the sun, which was visible in the southern countries of Europe. At Montpellier, where it was observed by Plantade and Capiés, the total obscuration lasted $4^{m}\ 10^{s}$.

During this time, the dark body of the moon appeared to be surrounded by a corona of pale light. The planets Venus, Mercury, and Saturn, and several of the fixed stars, were visible to the naked eye. On the summits of some of the mountains of Switzerland, where the view was not impeded by the gross vapours which accumulate in the lower regions of the atmosphere, the stars appeared as thickly strewed as in the time of full moon.

On the 3rd of May, 1715, there occurred a total eclipse of the sun, which was visible in London, and of which Halley has given an interesting account in a paper published in the 'Philosophical Transactions of the Royal Society' for the same year. The total obscuration lasted $3^{m}\ 22^{s}$. The planets Jupiter, Mercury, and Venus, as well as Capella and Aldebaran, were visible to the naked eye.

On the 22nd of May, 1724, a total eclipse of the sun occurred at Paris. The total obscuration lasted only a little more than two minutes. Venus, Mercury, and a few of the fixed stars were visible to the naked eye.

The next total eclipse of the sun recorded in history was visible in the northern countries of Europe. It occurred on the 2nd of May, 1733. The total obscuration lasted a little more than three minutes. The planet Jupiter, the stars of Ursa Major, Capella, and several other stars, were visible to the naked eye. Besides the corona, several reddish patches of light were seen around the dark body of the moon. This is the earliest allusion to the well known red prominences which have excited so much interest in recent years.

A total eclipse of the sun which occurred in the Southern Ocean on the 9th of February, 1766, was observed by the persons on board the French ship the Comte d'Artois. The obscuration lasted only 5·3 seconds.

On the 24th of June, 1778, a total eclipse of the sun was observed at sea by the Spanish Admiral Don Antonio Ulloa, while proceeding from the Azores to Cape St. Vincent. The obscuration lasted four minutes. The corona around the moon appeared in great splendour.

On the 16th of June, 1806, a total eclipse of the sun was visible in North America, at Kinderhook, in the state of New York, where it was observed by Don Joachim Ferrers. The obscuration lasted $4^{m}\ 37^{s}$.

Another total eclipse of the sun, which was visible in America, occurred on the 30th of November, 1834. At Milledgeville, Georgia, where it was observed by the French astronomer Nicollet, the obscuration lasted $1^{m}\ 15^{s}$. At Beaufort, South Carolina, two planets and four stars of the first magnitude were visible to the naked eye.

On the 7th of July, 1842, there occurred a total eclipse of the sun, which was visible in the south of Europe. At Perpignan, where the phenomenon was observed by the late M. Arago and other French astronomers, the complete obscuration of the solar disc lasted only $2^{m}\ 24^{s}$. In the countries of Eastern Europe, the interval of totality was somewhat longer. At Lipesk, it lasted $3^{m}\ 5^{s}$. The corona on this occasion was very conspicuous. Several red protuberances were also seen around the dark body of the moon.

On the 8th of August, 1850, there occurred a total eclipse of the sun, which was visible in the islands of the Pacific Ocean. At Honolulu, the chief town of the Pacific Isles, it was observed by M. Kutczycki, who has given an interesting account of the phenomenon in the 'Comptes Rendus' of the Academy of Paris for April 21, 1851. The red prominences were very conspicuous on this occasion.

The next total eclipse of the sun occurred on the 28th of July, 1851, and, having been visible in the northern countries of Europe, was observed by a great number of astronomers. The totality, generally speaking, lasted about three minutes. Several rose-coloured prominences were seen around the moon's limb.

On the 30th of November, 1853, there occurred a total eclipse of the sun, which was visible in South America. At Occaje, in Peru, it was observed by M. Moesta, director of the National Observatory of Santiago, in Chili. The totality lasted $2^{m}\ 59^{s}$. The planets Jupiter and Venus were very conspicuous. Antares, which was within 5° of the sun, was also distinctly visible. Several rose-coloured prominences were observed around the moon's limb.

On the 7th of September, 1858, there occurred a total eclipse of the sun, which was also visible in South America. At Paranagua, in Brazil, it was observed by M. de Mello, director of the Imperial Observatory of Rio Janeiro; by M. Liais, a French astronomer; and several other individuals despatched for the purpose by the Brazilian government. Several protuberances were seen. The corona appears to have exhibited a very complicated structure. The planets Venus, Mercury, and Saturn, besides Sirius, Canopus, and three other stars, supposed to be α and β Centauri and α Crucis, were seen during the totality.

The last total eclipse of the sun which we have to mention is one which occurred on the 18th of July, 1860. On this occasion, the moon's shadow first traversed a portion of the North American Continent; it then swept across the Atlantic, and subsequently scoured the entire breadth of the Spanish peninsula, the eclipse terminating in the French colony of Algiers. The phenomena of the eclipse were observed by a great number of astronomers, both official and private, who had repaired to Spain for that purpose from every country in Europe. The British government placed at the disposal of the observers from this country the steamship Himalaya, for the purpose of conveying them from England to the Spanish coast. A party consisting of between forty and fifty individuals, headed by the Astronomer-Royal, availed themselves of this liberal offer. The greater number of the observers disembarked at Bilbao, a town in the Bay of Biscay; the remainder proceeded to Santander, which is situate about 30 miles further west. An arrangement was made by which the observers distributed themselves as widely as circumstances would admit over the track of the moon's shadow, with the view of guarding against casualties of the weather. A party, consisting of Captain Jacob, late director of the Madras Observatory, the Rev. Dr. McTaggart of Glasgow, and the writer of the supplementary matter of this article, observed the eclipse from the southern slope of the Sierra de Tolonio, a lofty mountain-range, commanding a most extensive view of the valley of the Ebro, along which the moon's shadow was to pass. The total obscuration of the solar disc lasted $3^{m}\ 20^{s}$. The planets Venus and Jupiter were seen shining with great splendour. Persons whose attention was not distracted by other matters perceived also seven or eight fixed stars. The corona was unusually brilliant on this occasion. Several rose-coloured protuberances were also visible.

We shall now give a special description of some of the more prominent features of total eclipses of the sun.

The corona of light which surrounds the dark body of the moon during the totality of a solar eclipse has been remarked by more than one ancient author. Plutarch especially refers to it in very explicit terms. Speaking of total eclipses of the sun he says:—"But even although the moon were at any time to conceal the whole body of the sun, still the eclipse is deficient in duration as well as amplitude, for there is seen around the margin a certain brightness which prevents the shadow from being very deep." All modern accounts of total eclipses of the sun agree in describing the corona as a characteristic feature of the totality. Its light has been generally remarked to be of a pale silvery colour, and to diminish gradually in brightness from the moon's limb. Its breadth may be said to amount to half the moon's radius, but there extend from it rays of much greater length, causing it to resemble the *glory* which painters in Roman Catholic countries throw around the heads of the saints.

Whatever may be the physical cause of the corona, it is very plain from the accounts of observers, that its brightness is not the same during every eclipse. Thus M. Kutczycki states, that on the occasion of the total eclipse of 1850, the corona vanished at the very instant of the reappearance of the solar light. A similar statement is made by M. Moesta with reference to the total eclipse of 1853. On the other hand, in the case of the eclipse of 1860, the writer distinctly perceived the corona at least ten seconds before the totality. Certain other observers perceived it even earlier. It also continued to be visible for several seconds after the reappearance of the solar light. In consequence of the bright light of the corona, the darkness during the totality was not so intense as it usually is during the occurrence of such phenomena.

We shall now advert briefly to the rose-coloured protuberances seen around the moon's dark limb during the totality of a solar eclipse. These phenomena were first distinctly seen during the total eclipse of 1733, but they do not seem to have excited any interest until the observation of similar phenomena on the occasion of the eclipse of 1842 attracted the attention of astronomers to the subject. The following is a description by M. Mauvais of the protuberances as observed by him at Perpignan during the last-mentioned eclipse.

"A few seconds after the total obscuration, while endeavouring to measure the breadth of the corona, I perceived a reddish point at the inferior limb of the moon, which, however, did not project sensibly beyond the limb. After an interval of fifty-six seconds had elapsed from the commencement of the totality, the reddish point to which I have referred, transformed itself into two protuberances, similar to two contiguous mountains, perfectly well defined. Their colour was not uniform. Upon their slopes were seen streaks of a deeper tint. I cannot give a more exact idea of their aspect than by comparing them to the peaks of the Alps illuminated by the setting sun and seen afar off. After the lapse of one minute and ten seconds from the commencement of the totality, a third mountain was perceived to the left of the two others. It exhibited the same aspect as far as regards colour. It was flanked by some smaller peaks, but all were perfectly well defined. While this third mountain was in the process of issuing forth, the first two continued all the while to increase. They finally attained a height of about 2′. The interval between the two groups appeared to embrace an arc of about 25° on the moon's limb. The most considerable group, apparently the most western, seemed to me to be a few degrees to the left of the lowest point of the moon's disc."

Francis Baily, who observed the eclipse from a station in the vicinity of Pavia, in Italy, remarks ('Mem. Ast. Soc.,' vol. xv.) that the protuberances resembled mountains of prodigious elevation. Their colour appeared red, tinged with lilac or purple, or rather their aspect suggested the colour of the peach blossom. According to M. Littrow, who observed the protuberances at Vienna, their aspect, which was first white, changed to rose colour, and then to violet, and afterwards passed in a reverse order through the same tints. M. Otto Struve, who observed the eclipse at Lipesk, remarks, in reference to the rose-coloured protuberances, that a very large part of the moon's disc was garnished with a similar reddish bordering.

The red prominences which appeared during the total eclipse of 1851 have been well described by the numerous skilled observers who proceeded to the countries of Northern Europe for the purpose of observing the phenomenon. According to Mr. Lassell, they were of a most brilliant lake colour, a splendid pink, quite defined and hard. Mr. Dawes remarked a bluntly triangular pink body *suspended*, as it were, in the corona, and the distance of which from the moon's limb was observed to increase as the moon continued to advance over the solar disc. The isolated patch of light was also seen by the greater number of the observers of the eclipse.

M. Moesta, who observed the eclipse of 1853, remarked on the same side of the corona, with a very conspicuous protuberance, two darker spots, of a form approaching to a square, in apparent contact with the moon's limb. They seemed to indicate an interruption of the corona, or rather two apertures through which the dark ground of the heavens was visible. Their height above the moon's limb was estimated to amount to 1′.

The protuberances which appeared during the total eclipse of 1860 resembled in their general features those observed on previous occasions. One of them appeared isolated from the moon's limb, but was seen to approach the latter as the moon advanced over the solar disk.

The question has been much discussed, whether the red prominences seen during a total eclipse of the sun belong to the sun or the moon. The observations of the total eclipse of 1842 seemed to indicate that they are appendages of the sun, for it was remarked by several of the observers, that the protuberances on the western limb of the moon gradually increased in magnitude as the moon advanced over the solar disc, while those on the eastern limb similarly diminished in size, consequences which would necessarily result from the protuberances being situate behind the dark body of the moon. This view of the origin of the protuberances was also strengthened by similar observations made during the eclipse of 1851; but it was established beyond all doubt by the observations of the eclipse of 1860. On the last-mentioned occasion it was remarked by several observers, that as the moon advanced over the solar disk, the protuberances on the eastern limb of the moon which first came into view, gradually diminished in size, while those on the western limb, which at the commencement of the totality were invisible, gradually increased in dimensions. This interesting circumstance has also been indicated by photographs of the protuberances taken by Mr. Warren De La Rue, and by the Italian astronomer Professor Secchi.

Besides the protuberances which form so conspicuous an object during the totality of an eclipse, there has been generally observed at the parts of the moon's limb where the solar light disappears, and again at the parts where it reappears, a long red streak of light, apparently of the same physical nature as the protuberances, and tending to support the opinion that the whole surface of the sun is enveloped in such a substance.

Attempts have been made to connect the rose-coloured protuberances with the solar spots, but the results of a careful comparison of the two classes of phenomena do not seem to indicate the existence of any physical relation between them. Other observers have endeavoured, but with no better success, to account for the protuberances by means of the faculæ of the solar disk.

The most probable view of the nature of the more important phenomena which reveal themselves during a total eclipse of the sun, is that the corona represents an atmosphere about the sun, and that the protuberances are emanations from a substance enveloping the surface of the sun, and somehow connected with the generation of the solar light and heat.

We shall conclude this article with adverting briefly to a phenomenon, apparently originating in an optical delusion, which has been sometimes remarked on the occasion of total or annular eclipses of the sun. In the case of an annular eclipse, the western limb of the moon, previous to the formation of the annulus, exhibits an indented appearance, resembling a succession of beads. Almost immediately the beads become elongated, assuming the aspect of long black parallel streaks, uniting the limbs of the sun and moon. In the next instant these lines give way, as if they had been snapped asunder by the eastward motion of the moon, and the annulus then appears completely formed. The same succession of appearances has been witnessed when the eastern limb of the moon is approaching the corresponding limb of the sun. Phenomena of this nature were witnessed during the eclipses of 1724, 1737, 1748, and 1791. Nicolai also observed a similar appearance very distinctly during his observation of the annular eclipse of September 7, 1820, at Manheim. He remarked that about a second before the annulus was formed, the fine curve of the moon's disk, then in contact with the sun's limb, appeared broken into several parts; and in a moment these parts flowed together like drops of water or quicksilver near each other. De Zach, who observed the same eclipse at Bologna, also remarks that before the contact of the two limbs was effected, there was visible, not a continuous thread of light, but a number of luminous points, resembling a row of so many pearl beads, separated by dark intervals. But the most vivid description of the phenomenon has been given by Francis Baily, who observed the annular eclipse of May 15, 1836, at Jedburgh, in the south of Scotland. ('Mem. Ast. Soc.,' vol. x.) When the cusps of the sun, previous to the formation of the annulus, were about 40° asunder, a row of lucid points, like a string of beads, irregular in size and distance from each other, suddenly formed round the part of the circumference of the moon that was about to enter on the sun's disk. Its formation was so rapid that it presented the appearance of having been caused by the ignition of a fine train of gunpowder. His impression was, that the annulus had just been formed, but to his great surprise he found that the luminous points, as well as the dark intervening spaces, increased in magnitude, some of the contiguous ones appearing to run into each other, like drops of water; for the rapidity of the change was so great, and the singularity of the appearance so fascinating and attractive, that the mind was for the moment distracted, and lost in the contemplation of the scene, so as to be unable to attend to every minute occurrence. Finally, as the moon pursued her course, the dark intervening spaces (which at their origin had the appearance of lunar mountains in high relief, and which still continued attached to the sun's border) were stretched out into long, black, thick, parallel lines, joining the limbs of the sun and moon, when all at once they suddenly gave way, and left the circumference of the sun and moon in those points, as in the rest, comparatively smooth and circular; and the moon perceptibly advanced on the face of the sun. The same appearance, although in a reverse order, was witnessed on the breaking up of the annulus. While the limb of the moon was yet at some distance from the margin of the solar disk, a number of long, black, thick, parallel lines suddenly darted forward from the moon, and joined the two limbs as before. As these dark lines got shorter, the intervening bright parts assumed a more circular and irregular shape, and at length terminated in a fine curved line of bright beads, as at the commencement, till they ultimately vanished, and the annulus ceased to exist.

The phenomenon alluded to in the foregoing description, which has received the appellation of "Baily's beads," has been carefully sought for on the occasion of all the total and annular eclipses which have been observed in recent times, but no confirmation of its existence has been obtained except in a few doubtful instances. The most probable explanation of its origin is that which supposes it to be due to some imperfection connected with the optical qualities of the telescope.

SOLAR SYSTEM. We have given the elements of the planetary motions minutely in the several articles MERCURY, VENUS, &c., together with such physical peculiarities as belong to them severally, and independently of the System; the general phenomena of their motions have been deduced from the great principle of GRAVITATION; their history, as far as it is in the plan of this work to give it, has been treated in ASTRONOMY. It remains to bring together the dimensions of the various parts of the System, and to notice such points as could not properly find a place under any of the heads just mentioned.

By the Solar System is meant that collection of bodies which contains the Sun, the planets which revolve round him, their satellites, and such periodic comets as have had their returns successfully predicted. The system of the ancients includes the Earth as a fixed centre, with the Moon, Mercury, Venus, the Sun, Mars, Jupiter, and Saturn. That of the moderns includes at this day the Sun as a governing body (but not as a fixed centre), Mercury, Venus, the Earth (with the Moon), Mars, the group of minor planets (now amounting to sixty-four),* Jupiter and four satellites, Saturn (with his triple ring) and eight satellites, Uranus with four satellites, and Neptune with one satellite, besides a considerable number of periodic comets. The following symbols are used to represent the ancient members of the system, to which we add the received explanation, without expressing any opinion about it :—

☉ Sun.
☿ Mercury.
♀ Venus.
⊖ or ♁ Earth (modern).
☽ Moon.
♂ Mars.
♃ Jupiter.
♄ Saturn.

The symbol for the Sun is all that modern abridgment has left of a face surrounded by rays; Mercury has the caduceus, or rod, entwined by two serpents; Venus, a circular looking-glass with a handle; the Earth (a modern symbol) has a sphere with an equator, and also (with some) an inverted symbol of Venus. Those who first used it did not, we presume, know that they might be making a looking-glass turned upside down represent their planet. The symbol of the Moon is obvious; Mars has what remains of a spear and shield; Jupiter, supposed to be a symbol of the thunder (arm and hand holding thunder?); Saturn, an altered form of a mower's scythe, the emblem of time. But others have thought that Mercury was designated by putting σ and τ together, the initials of *στίλβων*; Venus, from the first and last letters of *Φωσφόρος*; Jupiter, from the first and last letters of *Ζεὺς*. These signs are found on very old manuscripts and gems, variously figured, but all with some general resemblance to the modern printed forms.

The four minor planets discovered about the beginning of the present century were also designated by symbols. Vesta had for its symbol ⚶, or an altar with fire on it; Juno was designated by a sceptre, ⚵; Ceres, by a reaper's scythe, ⚳; and Pallas by the head of a lance,

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* Since the article ASTEROIDS was written, eight additional members of the minor planet-group have been discovered, namely :—in 1859, Mnemosyne, at Bilk, by Luther; in 1860, Concordia, at Bilk, by Luther; planet 59, name unknown, at Paris, by Chacornac; Danaë, at Paris, by Goldschmidt; Titania, at Washington, by Ferguson; Erato, at Berlin, by Förster; in 1861, planet 63, at Naples, by De Gasparis; planet 64, at Marseille, by M. Tempel. The total number of asteroids accordingly now (March, 1861) amounts to sixty-four.

⚳. This mode of designation has recently been abandoned. It is now usual to distinguish the asteroids merely by a number, enclosed in a circle, indicating their place in the order of discovery.

Uranus has been distinguished by the initial letter of Herschel's name, with the symbol of a planet attached, ♅; Neptune has for its symbol a trident, ♆.

We are now to state the relative dimensions of the Solar System in a rough manner. This, we think, it may be useful to do in such a manner that any two planets may be compared with one another without computation. The planet Ceres is used to represent the group of minor planets.

And first, as to the relative distances from the Sun, we have the following table :—

☿	100	54	39	25	15	74	41	20	14
♀	187	100	72	47	26	139	76	38	24
⊖	258	138	100	66	36	192	105	52	34
♂	394	211	152	100	55	293	160	79	52
⚳	715	382	277	182	100	532	290	144	95
♃	1344	719	520	341	187	1000	545	271	176
♄	2464	1319	954	626	347	1833	1000	497	323
♅	4955	2652	1918	1259	690	3686	2010	1000	649
♆	7740	4140	3002	1980	1086	5760	3150	1560	1000

This table represents the comparative mean distances of the planets from the Sun. In each column one of the distances is made 100 or 1000, and the rest are expressed accordingly. Thus we see by inspection that Uranus is about 12½ times as far from the Sun as Mars; about 19 times as far as the Earth; about 26½ times as far as Venus; and about 7¼ times the mean distance of the four small planets. Also, taking the mean distance of the small planets, we see that the distances from the Sun are as the numbers 15, 26, 36, 55, 100, 187, 347, 690; and if we take the first away from all the rest, we have 11, 21, 40, 85, 172, 332, 675, 1071, in which it will be observed that each is about double of the preceding, except in the case of the last two numbers. Kepler had observed a progression, without assigning a law, and had also noticed that one term appeared to be missing. Bode assigned the law which has just been noticed, noticing also the apparently missing term. The existence of a planet between Mars and Jupiter was accordingly suspected; and at last, to the astonishment of astronomers, four little bodies, looking more like fragments of a planet than planets, were discovered at a distance from the Sun so near to that which had been suspected, that their mean distance fills up its place in the series as well as that of any other planet. It was of course immediately suspected (when only two had been discovered) that these were remains of some planet which had been shattered by explosion or other cause; and the encouragement which this idea gave to look for further fragments, was perhaps one of the main causes of the discovery of the remaining two. It has been already stated that the number of bodies constituting the group of minor planets now amounts to sixty-four. This law of Bode, as it has been called from the astronomer who first noticed it, may be thus expressed: if a be the distance of Mercury, and $a+b$ of Venus, then $a+2b$ is that of the Earth, $a+4b$ of Mars, $a+8b$ of the small planets, $a+16b$ of Jupiter, $a+32b$ of Saturn, and $a+64b$ of Uranus. The law fails, however, in the case of Neptune, the distance of which is $a+99b$, instead of $a+128b$.

To convert the above relative distances into actual ones, consider the distance from the Sun to the Earth as 23,984 mean semidiameters of the Earth, the mean semidiameter being 3956 miles; so that the distance in question is 95 millions of miles. The semidiameter of the sun is 111·454 times that of the earth; so that the distance of the Earth from the Sun may be called 215 semidiameters of the Sun. One of our objects in this article is to correct the absurd notions derived from the playthings called orreries, and the diagrams exhibited in books and lectures. Let the capital letter O of the type which stands at the beginning of the article in this work represent the Sun; then the Earth is a speck which would need a good microscope to show it; and its distance from the Sun is represented by 11 inches, or nearly two inches more than the length of one of our columns. Sir John Herschel describes the Solar System thus :—

Planet.	Object which represents it.	Representative of its distance from the Sun.
Sun.	Globe of 4 feet diameter.	
Mercury.	Grain of mustard seed.	164 feet.
Venus.	A pea.	284 feet.
Earth.	A pea.	430 feet.
Mars.	A rather large pin's head.	654 feet.
Ceres, &c.	Grains of sand.	1000 to 1200 feet.
Jupiter.	A moderate sized orange.	Half a mile.
Saturn.	A small orange.	⅘ of a mile.
Uranus.	A full sized cherry, or small plum.	A mile and a half.
Neptune.	A good sized plum.	Two miles and a half.

The *excentricity* of a planet means the fractional part of a planet's mean distance by which its greatest or least distance exceeds or falls short of the mean distance. Arranging the larger planets in the order of their excentricities, we have

For Venus .	·007	For Uranus .	·047	For Mars .	·093
„ Neptune	·009	„ Jupiter .	·048	„ Mercury	·206
„ Earth .	·017	„ Saturn .	·056		

That is, if the mean distance of Venus were called 1000, its greatest distance would be only 1007, and its least 993.

For the excentricities of the minor planets, see Asteroids.

We now give a table for the times of revolution, similar to that given for the distances :—

☿	100	39	24	13	6	20	8	3	2
♀	255	100	62	33	14	52	21	7	4
⊖	415	163	100	53	21	84	35	12	6
♂	781	306	188	100	42	159	65	22	11
⚳	1911	748	460	245	100	388	160	55	22
♃	4925	1929	1186	631	257	1000	412	141	66
♄	11950	4680	2878	1531	624	2428	1000	343	163
♅	34880	13660	8401	4467	1824	7082	2918	1000	489
♆	68060	26732	16400	8692	3524	13776	5740	1968	1000

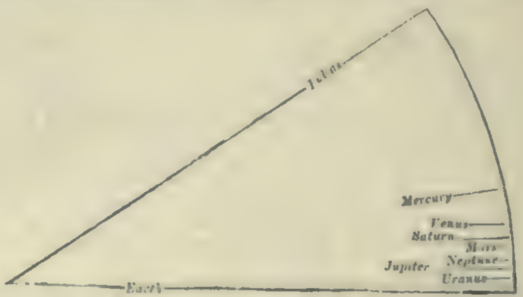
The explanation of this table resembles that of the preceding one—times, instead of distances, being the objects of comparison. Thus, if a revolution of Jupiter contain 1000 parts of time, that of Saturn has 2428 such parts; and the revolution of Uranus is 84·01 as long as that of the Earth.

In the following table will be seen the absolute time of revolution in days of each planet, and also numbers expressive of the intervals (in days) between two successive conjunctions with the Sun :—

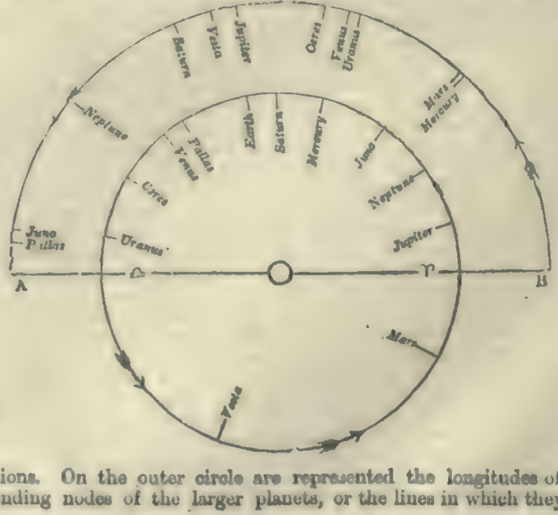
	Rev.	Int. of Conj.		Rev.	Int. of Conj.		Rev.	Int. of Conj.
☿	88	116	♂	687	780	♄	10759	378
♀	225	584	⚳	1681	467	♅	30687	370
⊖	365	—	♃	4333	399	♆	59860	368

Thus, Venus revolves in 225 days (all the numbers in this article are more roughly given than in the articles specially devoted to the planets); is in conjunction with the Sun at intervals of 584 days; and, with its mean motion, would describe 274° in the heavens while Jupiter describes 23°·1. Saturn moves 2·01 minutes daily; the Earth, 59′ 8″·3.

The minor elements (in a general consideration) may be best described by diagrams; the inclinations of the orbits may be represented by the following lines, which show the slope or inclination of each orbit to the orbit of the Earth or plane of the ecliptic. None of the old planets have an inclination of more than 7°, while in the new planets the same element varies from 40′ (Massilia) to 35° (Pallas).



In the next figure the plane of the ecliptic is represented: A B is the line which points to the astronomical first point of Aries, or the vernal equinox, and the arrows represent the directions of the planetary



motions. On the outer circle are represented the longitudes of the ascending nodes of the larger planets, or the lines in which they are found when they rise through the ecliptic from the southern to the northern side of it. On the inner circle are represented the longitudes of their perihelia, or points of nearest approach to the Sun. The slow changes which take place in these elements are noted in the articles devoted to the different planets.

A general view of the elements of the minor planets has already been given. [ASTEROIDS.]

Jupiter and his satellites might be inclosed in a sphere having a radius of about 2½ times as great as that of the Sun; Saturn and his satellites in a sphere of 7¾ the radius of the Sun; Uranus and his satellites in a sphere of 4½ the radius of the Sun; and Neptune and his satellite in a sphere of which the radius is a little greater than the Sun's radius. The Earth and Moon [MOON] might be contained in a sphere of one-half the radius of the Sun.

In apparent diameter Mercury varies from 5″ to 12″; Venus from 10″ to 61″; Mars from 4″ to 18″; the small planets have diameters hardly measurable; Jupiter from 30″ to 46″; Saturn from 14″ to 18″; Uranus from a little less to a little greater than 4″; Neptune oscillates about 3″.

If the radius of the Sun were divided into 1000 parts, there would be as follows in the radii of the several planets:—Mercury, 3½; Venus, 8¾; the Earth, 9; Mars, 4⅞; Jupiter, 97½; Saturn, 85; and Uranus, 39. If the bulk of the Sun were divided into a *million* of parts, Mercury would be a little less than one-twentieth of one of the parts; Venus, two-thirds of a part; the Earth, three-quarters of a part; Mars, one-tenth of a part; Jupiter, 925 parts; Saturn, 720 parts; Uranus, 58 parts; Neptune, 120 parts. The Moon is about the third part of Mercury in bulk.

The masses of the planets vary very much from what they would be if they were nearly of the same substance. From the effects of the planets in attracting their satellites, compared with the effects of the Sun upon themselves, it is found that if, according to Cavendish's experiment, we take the Earth to be, at a mean, 5½ times the density of water, or about half that of lead, the Sun may be considered, as to density, to be made of asphaltum, or rather heavy coal; Jupiter, of the same; Uranus and Neptune, each of a material very little heavier; Saturn, of maple-wood; the Moon, of diamond or topaz. By other modes, of course, than that of their satellites, Mercury is found to be three times as dense as the Earth; Venus, of about the same density; and Mars, about three-quarters as dense as the Earth.

The Sun revolves about its axis in about 25½ sidereal days; Mercury, Venus, the Earth, and Mars, all revolve in about the same time, from 23½ʰ to 24½ʰ; Jupiter and Saturn severally revolve in about 10ʰ and 10½ʰ. About Uranus and Neptune, nothing is known in this respect.

From what precedes, a sufficient general notion may be collected of the dimensions of the Solar System, and we now proceed to some other points connected with it. As to its place among the fixed stars, it is only within the last twenty years that the distance of any star from our system may be said to have been positively measured. [PARALLAX OF THE FIXED STARS.] The star 61 Cygni is shown to be more than 340,000 times as far from our system as its most distant discovered planet is from the Sun. As to the question of the motion of the Solar System in space, consult the article which follows.

The next question may be, is there any evidence in our System of any secondary law of formation, indicating a connection between the mode of creation of one planet and another? The will and power of the Creator are the final causes both of the initiation and maintenance of this vast machine; but in the latter there are visible secondary laws, that of attraction, for instance: were there any in the former? Attempts at investigation on this point have been frequently considered atheistical; a foolish notion, arising out of those views to which we have alluded in MOTION. Those who can only think of the *Creator* and forget the *Maintainer*, and who virtually separate the office of the latter, and give it to the "laws of nature," may reasonably fear that they would have to give up also the former office to the "laws of creation," if such were found; which would be (but owing only to their own interpretation of the manner in which the world *continues* to exist) a renunciation of the idea of Deity in the contemplation of the manner in which it *began* to exist. But to those who keep constantly in view the fact which no modern theist disputes, that the same power which created continues to create in preserving, and that the "laws of nature" are only expressions of the manner in which this preservation is seen to act, will look upon the "laws of creation" to be as simple and natural an object of philosophical inquiry as those of the ascent of sap in a plant, or of the revolution of a planet. The proper reply to a charge of atheism brought against those who investigate any mode of action of the Creator of the universe, at any *past* time, is the retort of semi-atheism against those who make it.

Many speculations have been made upon the formation of the several planets, but none which has any appearance of connecting the phenomena of one planet with those of another, except by Laplace ('Système du Monde,' vol. ii., note 7), in what has been called the nebular hypothesis. This conjectural theory, which is well worthy of attention, never received any particular notice, to our knowledge, from any writer in this country, until Mr. Whewell's 'Astronomy and General Physics,' the third of the Bridgewater Treatises, appeared, in which it is announced that the nebular theory was ushered in with expressions which showed Laplace to be a professor of atheism. What Laplace really thought on these subjects, as we have said before [LAPLACE, in BIOG. DIV.] we do not know, nor would it really matter if he were what he was represented to have been; for a conjecture may be ingenious, and a theory sound in its details, even though its author made it stand in the place of a Creator. But considering the collateral associations connected with such a charge, it will be well to examine into the fact whether there was any such announcement; and to do this fairly, we must quote both Mr. Whewell and Laplace. The former says, "We have referred to Laplace as a profound mathematician, who has strongly expressed the opinion that the arrangement by which the stability of the Solar System is secured is not the work of chance; that 'a *primitive cause* has directed the planetary motions.' This author, however, having arrived, as we have done, at this conviction, does not draw from it the conclusion which has appeared to us so irresistible, that 'the admirable arrangement of the Solar System cannot but be the work of an intelligent and most powerful Being.' He quotes these expressions, which are those of Newton, and points at them as instances where that great philosopher had deviated from the method of true philosophy. He himself proposes an hypothesis concerning the nature of the *primitive cause,* of which he conceives the existence to be thus probable."

Here are two assertions:—1. That it is the doctrine of an intelligent Creator which Laplace "points at" as a deviation from true philosophy; 2. That Laplace proposes his nebular hypothesis as a primitive cause. We pay a writer of Mr. Whewell's character the compliment of inserting here matter which would more appropriately appear in a review of his work: and we deny that Laplace has been well described in either assertion. Our object is to clear the nebular hypothesis from the unphilosophical character with which its first appearance is thus presented, and by no means to uphold the moral dignity of Laplace. Until the biting facts connected with his treatment of his benefactor are answered or explained, that great mathematician must be called a time-server; and we suspect that his 'Système du Monde' only treats the intelligent Creator whom his mind acknowledged in the same manner as he afterwards treated Napoleon. It was published in 1796, a period which would well explain the mere suppression of all allusion to the Supreme Being: and one of these things must be true; either Laplace was what Mr. Whewell styles him, or he had not the courage to declare himself otherwise in his age and country. But what we have here to do with is the assertion that he did more—that he *attacked* the doctrine of a Supreme Being. His words are as follows, the passages to which we wish to draw attention being in Italics:—"I cannot here help observing how much Newton has departed on this point from the method which he elsewhere so happily applied. After the publication of his discoveries, this great geometer, abandoning himself to speculations of another nature, *inquired into the motives which made the Author of nature give to the solar system* the constitution which we have described." Laplace then quotes Newton's Scholium [PRINCIPIA, cols. 742–743, where we have translated the whole] thus: "*And all these regular motions have no origin in mechanical causes,*"[*] &c., &c., down to "all parts of the heavens." He then further quotes, "This most elegant group, &c., can only arise from the design and government of a powerful and intelligent Being." He (Laplace) continues thus, speaking, so far as the mere notion of a Supreme Being is concerned, rather in approbation: "He repeats the same thought at the end of his 'Optics,' in which he would have been still more confirmed if he had known what I have demonstrated, namely, that the arrangement of the planets and satellites is precisely that which makes a certain provision for their stability. 'Blind destiny,' says Newton, 'can never make the planets move thus with such small irregularities, which appear to come from the mutual action of the planets and comets, *and which will probably become greater and greater in the course of time, until at last the system will again require its Author to put it in order.*' But," proceeds Laplace, "may not this arrangement of the planets be itself a consequence of the laws of motion? and may not the Supreme Intelligence, which Newton makes *to interfere,* have already made it depend upon a more general law? *Are we to affirm that the* [unlimited] *preservation of the Solar System is a part of the intentions of the Author of Nature?*" This we should sum up as follows:—Laplace charges Newton with a departure from philosophical principles in—1, speculating on the motives of the Creator;[†] 2, assuming the probability that his works would not last his time without his own supernatural interference; 3, assuming that he intended to preserve the Solar System for ever. But Mr. Whewell singles out only one part of Laplace's quotation, and, without paying any attention to the remarks which explain his meaning, declares that Laplace "pointed at" Newton's declaration of belief in God as a piece of bad philosophy; whereas this part of his quotation is only followed by the remark how much stronger he himself (Laplace) had been able to make the sort of evidence on which Newton rested; and the sentence selected by Mr. Whewell as "pointed at," coupled with the remark specially made on that sentence, has rather the appearance of being pointed at with approbation. With regard to the assertion that Laplace propounded the nebular theory as a *primitive cause*, it is true that he did so in his own sense of the words. Mr. Whewell means by primitive cause a first cause, as those words are usually understood; and he asks (and the question would have been much to the purpose if Laplace had really meant the same thing as himself by the words *primitive cause*), "Was man, with his thought and feeling, his powers and hopes, his will and conscience, also produced as an ultimate result of the condensation of the solar atmosphere?" But Laplace speaks as follows:—"Quelle est cette *cause primitive?* J'exposerai sur cela, dans la note qui termine cette ouvrage, une hypothèse," &c. And in the very first words of this note we find, "On a, pour remonter à la *cause* des mouvemens *primitifs* du système planetaire," &c. This then is what Laplace understood by *primitive cause*, a *cause* of the *primitive* motions;—an improper use of language, if the reader pleases; but when a man puts his own meaning on his own words, no one has a right to fix the consequences of another meaning upon him.

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[*] Laplace evidently thought that by mechanical causes Newton meant what we now call second causes. See the reference just made.

[†] Newton's Scholium does not seem to us to do any such thing; but that is not the question. Laplace's approval or disapproval is of course to be applied to his own interpretation of Newton's meaning, not to ours.

We now proceed to the nebular theory, which is a conjecture proposed with much doubt by Laplace, as a possible explanation of the manner in which the *motions* of the several planets obtained those remarkable resemblances which are found to subsist, without making the inquiry extend to anything except their motions. All the planets move in one direction round the sun, and their satellites move in the same direction round themselves; those that are known to revolve round their axes (and the contrary has been proved of no one of them) also revolve in the same direction, and their equators are not much inclined to their orbits. The excentricities of the planets and satellites are in no case very large, and generally very small; and the inclinations of their orbits to one another are generally small. Many nebulæ in the heavens appear, when examined, to consist of a bright nucleus surrounded by nebulous matter; in others it is found that the apparently nebulous matter consists of stars. This gave Laplace the idea that our System might originally—that is, previously to the establishment of its present order—have been a large nebula, of which the sun was at the centre. Imagine a large nebulous mass in a state of revolution, with a solid, or at least less nebulous, centre, round which it revolves: call this central nucleus the sun. Assume the ordinary laws of matter to be true of this nebulous mass; and also that it extends as far as such an atmosphere can do—namely, until the attraction of the whole upon particles at the equator is equal to the centrifugal force of those particles. If condensation should begin to take place, arising from loss of heat, the mass would revolve more and more rapidly as it was condensed into less and less space; but it does not follow that the equatorial particles would fall in towards the centre: they are balanced by the equality of the centripetal and centrifugal forces, and might form a ring round the rest of the mass. If the process were conducted with great regularity, this ring and the mass of vapour might undergo continual condensation together, until the increasing velocity of rotation prevented the formation of the ring from continuing. The departures from complete regularity which might exist in the mass might cause disturbances in the formation of the rings, which might end in there being one or more (not many) permanently revolving round the rest of the mass condensed into a solid body, in the manner of Saturn and its rings. Such regular formation, however, might be rarely continued long enough; and if the rings got broken, each ring would become several masses, which would revolve nearly at the same distance, and nearly with the same velocity: such a result is seen in the four small planets. But as, generally speaking, these masses would, by irregularities in their velocities, be combined into one [*] at last, each broken ring would form a new nebulous mass, revolving round the diminished central nucleus; and if a number of such masses were formed, those nearer to the central mass would move with the greater velocity, and would be both smaller and denser than the external ones: the first circumstance certainly, the second and third most probably. Again, each mass would have a motion of revolution in the same direction [Motion, Direction of] as the motion round the primary; for when the ring becomes broken, its internal parts have a somewhat more rapid motion than the external ones, which would give the motion of rotation noticed. And the rotations thus created in the internal masses would probably be greater than those in the external masses. The orbits of the masses would necessarily be nearly circular, and not much inclined to each other; but for irregularities, quite circular, and in the same plane. In each of the nebulous masses thus detached and revolving, condensation might again give rings or satellites, or both; but in all probability the external masses would get more satellites than the internal ones: the orbits of the satellites must be also nearly circular, and not much inclined. All the preceding circumstances, both those which are certain and those which are probable (Laplace confined himself to the former), are actually existing in the Solar System; consequently this hypothesis, though subject to serious difficulties, deserves attentive consideration, as often as any new knowledge of the constituent parts of our system shall render a reference to it likely to produce evidence on one side or the other. As a substitute for intelligent creative power, if such a thing were intended, it would do no better than any other; for, as Mr. Whewell observes, a man with will, power, and conscience, cannot be admitted to be a necessary consequence of the cooling of a nebulous atmosphere. Nevertheless, as exhibiting a possible mode in which the Creator of mind and matter made the laws of formation resemble those of continuation, as far as the motions of the system are concerned, this hypothesis is strikingly explicative of what we really see. But even if we were to take it to be a true explanation, it would only be one step of the ascent, and the next question would be, what higher process distributed the parts of this nebulous mass in such a manner as to place those outermost which were fit to form a planet so distant from the source of light and heat as Neptune, and to support the appropriate forms of animal and vegetable life which analogy would induce us to suppose must exist there.

The history of astronomy teaches us that the system in which we live has not undergone any apparent change for more than 2000 years; and, on inquiring into the connection which exists between one planet and another, or the laws of gravitation, it is found that so far as their mutual actions are concerned, there is no reason why any change ever should take place. If the central body were the only one which attracted the rest, and as long as the laws of matter remained unaltered, it is certain that nothing could alter the revolutions of a system of planets, unless two orbits intersected, and the planets of those orbits happened to come to the intersecting part at the same time, and to strike each other. But the planets are subject to the action of each other as well as to that of the sun, and no instant elapses without every orbit undergoing a slight change from every one of the planets of the other orbits. Jupiter alone produces on the earth's orbit in one year more change than we have any right to say all the comets put together would do in a hundred. And yet the system not only continues without any sensible change, but, one circumstance alone excepted, to which we shall presently allude, is demonstrably formed to continue for a most enormous length of time, unless some new action should arise, or some external cause begin to operate. As it is sometimes stated that a complete mathematical demonstration has been given of the *eternal* stability of the Solar System, so far as the mutual actions of its parts are concerned—an assertion which is altogether incorrect—it may be worth while to enter a little on the details of this subject.

The disturbing forces of the planets on each other cannot have their effects calculated all at once; but each force must be divided into an infinite series of terms, the first of which contains all the terms of the first dimension, the second all those of the second, and so on. Of all these terms each is much less in its effect than the preceding; so that in fact the first two dimensions are all that produce any sensible effect in any time which it is worth while to consider. Occasionally it happens that terms of the third and fourth dimensions have been required to be used, but almost all the sensible perturbations of the system depend on terms of the first two orders. As far as any effects arising from such terms are concerned, Lagrange and Poisson are admitted on all hands to have demonstrated the stability of the Solar System: and considering the nature of the process employed, and there being no appearance of any circumstance which looks likely to lead to a different result in any of the remaining terms of the disturbing forces, it may be highly probable that a further investigation would show the same thing, if all the dimensions of the disturbing forces were employed. Sir J. Lubbock ('Phil. Mag.,' February, 1831) has pointed out the forms which further investigation would apparently produce, and which would (unless a detailed investigation should lead to something not discoverable *à priori*) bear out as certain what we have just stated to be probable. But though all the presumptions lie on the side of those who would assert the proposition absolutely of all dimensions of the disturbing force, it is not yet time to say that it is a certain mathematical consequence of the theory of gravitation.

When the effects of perturbation are examined, as far as the second dimension of the disturbing force, it appears that the immense mass of the sun compared with that of any planet, the great distance of the planets from each other as compared with their amounts of departure from spherical form, the small excentricities and inclinations of their orbits, and their motions being all in one direction, give the following mathematical consequences of the law of attraction:—First, the longest or major axes of the planets' orbits are not subject to any slow variations of very long period; all their variations being excessively small, and soon destroyed by the production of contrary variations. It is very often stated that the major axes are subject to no variation; this is to be understood only of *secular* variation (or of a very long period). One year is not precisely the same as another to any fraction of a second; but the average year of one long period *is* precisely the same as that of another; or at least the mean years of the two periods become more nearly equal the longer the periods are made. But the excentricities and inclinations are subject to long periodic alterations, the times of their recurrences not being exactly settled, from the difficulty of their determination. How then is it known that they are periodic? For instance, the excentricity of the Earth's orbit is subject to a yearly diminution of ·00004, its value in 1801 being ·017. Had this diminution been an increase, as it is in Mercury and Jupiter, it might *à priori* appear possible that this increase should continue until the orbit (preserving the same major axis) should be so elongated that the ultimate approach to and recession from the sun should give our planet the alternate climates of Mercury and Mars, and thus no doubt destroy it as the abode of beings constituted like ourselves. It is found, however, that the following relation must exist :—If at any one moment the square of the excentricity of each planet be multiplied by its mass and the square root of its mean distance from the sun (represented in numbers), the sum of all these products must be the same as it was at any moment past, or will be at any moment future. And if in each product the tangent of the inclination to a fixed plane be substituted for the excentricity, the resulting equation is true. From such relations as these, and others connected with them, it is shown that so far as the mutual actions of the planets are concerned, no one excentricity nor inclination can increase indefinitely, but all their changes must be periodic, and confined within rather small limits. The approach of the ecliptic to the equator, for instance, which amounts to about half a second in a year (and which leads speculators sometimes to talk about a past time when the ecliptic passed through the pole, and a future time when it will coincide with the equator), must stop long before the ecliptic reaches the equator, and attain a minimum inclination, after which the two will begin to separate; the whole oscillation being less than three degrees. The whole result is summed up thus: As far as terms of the second order (inclusive) in the disturbing forces, and as long as only the mutual attractions of the planets act, there is a mathematical certainty that the Solar System will remain in its present state, the elements of the different orbits oscillating about certain mean values, from which they are never very distant : except only the longitudes of the nodes and perihelia, which change with velocities which are always very near to certain mean velocities. The probability is very small that the higher dimensions of the disturbing forces would affect this result, and certainly only in a length of time to which the longest periods known are trifling in comparison.

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[*] If any number of masses, capable of cohering, revolve in orbits so near to one another, that they must cohere when they come to their minimum distance, nothing but an absolute and mathematical equality in their mean velocities can keep them permanently asunder; the smallest inequality must at last bring them all together.

This last point, however, is of the less importance, since it has become highly probable, within the last few years, that an external cause does exist, which must, unless there be a counteracting force of which we know nothing, in time cause the destruction of the System. If the planets move in any medium which resists their motions, however little, the consequence must be a gradual diminution of their mean distances from the sun, and a gradual increase of their velocities, ending in their absolutely falling into the sun. For the presumption in favour of the actual existence of such a resisting medium, see COMET. This retarding agent seems to show a rapid effect upon so attenuated a mass as Encke's comet, though thousands of years have elapsed without its producing any sensible effect upon the planets. Little as it may concern us directly, these speculations have an interest, both as to the glimpse they give of the possible destiny of our System, and from their association with the history of past and the hope of future discovery. It is to be remembered that no science has drawn out so much of mathematical talent, or indirectly excited such an influence upon other branches of physical research, as the application of the theory of gravitation to the development of the planetary motions.

SOLAR SYSTEM, MOTION OF THE, IN SPACE. One of the most interesting results of modern astronomical research consists in the discovery of the fact, that many stars of the class styled *fixed* stars, are in reality subject to a minute movement, in virtue of which their positions in the celestial sphere are slowly shifting from year to year. This proper motion was originally found to be applicable only to a few of the principal stars, but as the observations of astronomers have acquired a greater degree of precision, the number of stars which appear to be slowly changing their position continues to increase, and the probability is, that there is no star in the celestial sphere whose position is absolutely fixed. But the results at which astronomers have arrived with respect to the parallax of the stars, combined with the relative intensities of the light of the sun and the stars, as determined by photometric experiments, tend strongly to confirm the idea that the sun is neither more nor less than a star. It is reasonable then to suppose that the sun, like the stars, should be subject to a motion of translation in space. This idea seems to have first suggested itself to Fontenelle, who refers to it in a notice on the labours of Cassini. Bradley also, at the close of his paper in which he announces the discovery of the nutation of the earth's axis, has remarked that the apparent motion of the stars may arise either from a real motion of the stars themselves, or from a motion of the solar system in space. But he was of opinion, that ages would elapse before astronomers would arrive at a definitive conclusion on this subject.

Thomas Wright, in his 'Theory of the Universe,' published in 1750, suggests, as very probable, that the sun, with his attendant planets, may be circulating round some other centre. Mayer was the first astronomer who endeavoured to deduce a trustworthy result from an examination of the proper motions of the stars. His researches were based upon a comparison of the places of eighty stars, as observed by Römer in the year 1706, with the corresponding places as determined by Lacaille and himself about the middle of the same century. The conclusion at which he arrived was, that the proper motions of the stars do not afford any evidence of a motion of the solar system in space. A remark made by Mayer on this occasion is worthy of mention. He states, that if the solar system is advancing to any particular region of the heavens, the stars in this direction will necessarily be gradually receding to a greater distance from each other, while, again, those in the opposite direction will appear to be drawn closer together. In 1783 the elder Herschel having been induced to examine the subject, arrived at a result quite different from that obtained by Mayer. His investigation was founded on the proper motions of seven of the brightest stars, as determined by Maskelyne. The result of his inquiry indicated a motion of the solar system towards a point in the heavens near the star λ Hercules, which he found to be situated in 257° of right ascension, and 25° north declination. In 1805 he subsequently resumed the subject, and obtained for the point towards which the solar system is moving, the following co-ordinates : right ascension, 245° 52′ 30″; north declination, 49° 38′.

The same subject was considered about the same time by Prévost and Klügel, whose results agreed tolerably well with those obtained by Herschel. On the other hand, Biot and Bessel, who examined the subject, arrived at the conclusion that the present state of our knowledge respecting the proper motions of the stars is insufficient to afford any trustworthy indication of the existence of a motion of the solar system in space. In recent times, however, the researches of Argelander, Lundahl, and Otto Struve, have confirmed the views of Sir William Herschel. The researches of these astronomers were based upon an examination of the proper motions of stars chiefly in the northern hemisphere. The late Mr. Galloway, however, obtained very nearly the same result by an examination of the proper motions observed in the southern hemisphere by Lacaille about the middle of the last century, and again by Johnson and Henderson in recent times. By combining his own result with the results arrived at by Argelander and Lundahl, he obtained the following values for the co-ordinates of the point in the heavens towards which the solar system is advancing :—

Right Ascension .	259° 9′·4,
Declination N. .	34° 36′·5,

these numbers referring to the equinox of 1792.

The most recent examination of this subject is due to Mr. Airy, who by a method totally different from that employed by previous inquirers has obtained a result agreeing very nearly in right ascension, but differing considerably in declination, from that hitherto arrived at.

SOLDERED JOINTS. When two pieces of metal of the same or of different natures are joined by the interposition of another metal of a more fusible character than that of the pieces to be joined, it is said that they are *soldered* together, or occasionally that they are *brazed* together. Thus, when lead has to be joined to lead, the surfaces of contact are scraped perfectly clean, and a mixed metal, composed of about $\frac{2}{5}$ of tin to $\frac{3}{5}$ of lead, is melted over the joint so as to effectually adhere to the respective surfaces. When lead has to be joined to brass, the soldering metal is usually composed of a mixture of 7 parts of tin to 5 of lead, and this alloy is also used for soldering tin pipe, or for repairing the joints of tinned iron-ware. When iron plates are joined together by soldered joints, or when copper, tin, or lead pipes are joined to iron work, the brazing or soldering metal used is composed of about 4 parts of zinc to 3 of copper, or more properly speaking, of 2 parts of fine brass to 1 of zinc, the brass consisting itself of 2 of copper to 1 of zinc. The joints themselves may be either butt joints, lapped joints, spiggot joints, crossed, or flat joints. Wrought-iron joints upon wrought-iron are made by *welding*, as also are the joints of wrought-iron upon steel, whenever it is possible to place the respective pieces in the smith's forge; the more unmanageable joints are usually brazed.

SOLDERING is the process of uniting the surfaces of metals, by the intervention of a more fusible metal, which, being melted upon each surface, serves, partly by chemical attraction, and partly by cohesive force, to bind them together. In the ordinary soldering, the alloy used as a solder must be more fusible than the metals to be united, and must have a strong affinity for them. To insure perfect union between the solder and the surfaces to which it is applied, it is essential that they be made perfectly clean and free from oxide, and that the atmosphere be excluded during the operation. This is effected in various ways, but most commonly by the use of borax, sal ammoniac, or resin, either mixed with the solder or applied to the surfaces to be joined.

The kinds of solder used for the several metals are given under SOLDERS.

Articles of *wrought-iron*, and some qualities of *steel* also, may be soldered with cast-iron; the cast-iron being repeatedly heated and quenched in water, by which it becomes sufficiently friable to be beaten to a coarse powder with an iron pestle and mortar. In making fine steel instruments, gold, either alone or with a slight alloy of copper, is often used as solder. Silver solder, being less expensive, and nearer the colour of the steel, is preferred by some for this purpose. In larger articles of iron and steel, a solder consisting of equal parts of tin and iron is sometimes used.

Common *plumbers'* solder is made of two parts lead and one part block tin; or of the same metals mixed in nearly equal quantities; bismuth is added when it is desired to make the alloy more fusible. Soft solder has two parts tin to one lead; and other alloys of tin, lead, and bismuth, are used for uniting various articles of lead, tin, pewter, and other soft compounds. Such highly fusible solders are usually cast in ingots or strips, and melted as they are used by means of an instrument called a soldering-iron, which is tipped with copper.

A curious mode of soldering is resorted to in order to fix upon the back of the dial-plate of a watch the small copper studs by which it is attached to the plate that encloses the wheel-work. The heat required for melting spelter solder would be injurious to the enamel, and therefore the studs are made of wire plated with silver, and fixed by melting the silver on their sides, and causing it to run down to their base, where a mixture of borax and water is previously laid. Thus the studs are fixed without applying the jet of the blowpipe immediately to the back of the enamelled plate.

A kind of soldering, called *burning-to*, is practised in some cases with sheet-lead, where it has been desirable to make a vessel entirely of that material; the junction being effected by pouring melted lead upon the edges to be united, until they fuse together. Somewhat similar to this is the process of *autogenous soldering*. This process, the invention of M. de Richemont, consists in the union of two pieces of metal without the interposition of any solder, by fusing them at the point of junction by jets of flame from a gas blowpipe. The apparatus used for the purpose contains a hydrogen gas generator, bellows for atmospheric air, and valves for regulating the proportion in which the gas and air are to be mixed. The joints formed in this way are neater and less liable to flaws than those made by the common process. Mr. Spencer discovered this process about the same time as M. de Richemont; and his experiments led him to suppose that, by varying the admixture of gases, a jet of flame might be produced of intensity suitable for any metal to which it may be desired to apply this mode of soldering.

The recent investigations concerning the applicability of the metal *aluminium* to purposes of use and ornament, have necessarily included the preparation of some kind of solder. It is found that aluminium cannot be soldered in the ordinary way. M. Mourey, of Paris, has devised the following plan. He puts on each surface a solder of zinc and aluminium, so as to form a thin film. Then, with a solder richer in aluminium, he joins the two pieces together. The first solder thus adheres to the metal, and the second solder to the first. The surfaces of aluminium are in the first instance prepared by a mixture of turpentine, balsam of copaiva, and lemon-juice, and strongly heated. The solder No. 1 consists of 6 aluminium and 94 zinc; No. 2 of 20 aluminium and 80 zinc.

SOLDERS. A name given to certain alloys used for uniting metallic surfaces by fusion, to effect which it is necessary that the alloy should fuse at a temperature below the melting point of the metallic surfaces to be joined. The following are some of the most important solders. [ALLOYS.]

Solder for gold	Gold (16 carats)	66·6
	Silver	16·7
	Copper	16·7
		100·0
Solder for silver	Silver	66·6
	Copper	30·0
	Brass	3·4
		100·0
Solder for brass	Copper	50
	Zinc	50
		100·0
Soft solder	Lead	67
	Tin	33
		100·0

SOLDIER is a term applied now to every man employed in the military service of a prince or state, but it was at first given to such persons only as were expressly engaged, for pay, to follow some chief in his warlike expeditions. Cæsar mentions a band of 600 men called "soldurii," who bound themselves to attend their leader in action, and to live or die with him ('De Bello Gallico,' iii. 22), but it does not appear that they served for pay. By some the word has been thought to come from "solidus," the name of a coin under the Roman empire, which may have been received as the payment for the service.

The troops which formed the armies of the Crusaders were engaged to serve for pay, for though the nobles voluntarily entered into the war, their vassals were not obliged by the tenure of their fiefs to accompany them. Père Daniel ('Hist. de la Milice Fr.,' tom. i., p. 103) expresses his belief that Philip Augustus, near the end of the 12th century, was the first of the French kings who had hired troops, at least in any considerable body, in his service; and the practice of retaining such troops appears to have been afterwards very general. It is probable that men hired for the wars were, from the time of that prince, called soudoyers or souldyours, that is, stipendiaries; but the name appears for the first time in the 'Chronicles' of Froissart, where it is applied to the hired troops both of France and Germany.

In the wardrobe account of Edward I. (1300) the term soldier occurs frequently, and Grose considers that the persons so designated were of a different class from the other troops. Some of them are called "soldiers scutifers,' or esquires; some, "soldiers constables;" and others, simply "soldiers;" but the pay of all was the same, namely, one shilling per day. ('Mil. Antiq.,' vol. i., p. 326.) From the time of Edward I. to the end of the reign of Edward III. the daily pay of a banneret was 4*s.*, and of a knight 2*s.*; that of a hobiler, a sort of light horseman, was 6*d.*; of a crossbowman, 4*d.*; and of an archer, 2*d.* In that age the stipendiary troops, or soldiers, were raised in England by commissions granted by the king to persons who undertook to enlist men for a certain pay (which was made to depend on the nature of the service), and for a certain portion of the ransom-money which might be obtained in the war.

Little change seems to have taken place in the pay of the English soldiers between the times of Edward III. and Mary. We find that during the reign of this queen the daily pay of a captain of heavy cavalry was 10*s.*, and of a cavalry soldier, 1*s.* 6*d.* The pay of a captain of light cavalry was 6*s.*, and of a soldier 1*s.* The pay of a captain of foot was 4*s.*; of a lieutenant, 2*s.*; of an ensign, 1*s.*; and of a foot soldier, 8*d.*; a halbardier and a hackbutter, on horseback, had each 1*s.* daily. In the times of Elizabeth, James I., and Charles I., the pay of the officers was a little raised, but that of a private foot-soldier was still 8*d.* per day; during the civil wars the pay of the latter was 9*d.*, but in the reign of William III. it was again reduced to 8*d.* At that time the pay of a private trooper was 2*s.* 6*d.*, and that of a private dragoon was 1*s.* 6*d.*, including in both cases the allowance for the horse. It is evident that the pay of the private soldier in later times is far from having been raised in the inverse ratio of the value of money.

While armour was in general use, the common soldiers of England were distinguished only by scarfs or by badges, on the latter of which were impressed the arms of their several leaders; but in the reign of Henry VIII. something like a uniform was worn, and it appears that the colour of the men's upper garments was then generally white; the soldiers in the king's particular service only, had on their coats a representation of the cross of St. George. However, on an army being raised in 1544, the soldiers were ordered to wear coats of blue cloth bordered with red. White cloaks marked with red crosses continued to be the uniform of the troops during the reign of Queen Mary; but in the time of Elizabeth the infantry soldiers wore a cassock and long trowsers, both of which were of Kentish gray: the cavalry were furnished with red cloaks reaching down to the knee and without sleeves. Gray coats, with breeches of the same colour, continued to be the uniform as late as the end of the reign of William III., but soon after that time red became the general colour for the coats of the British infantry soldiers.

It must be admitted that, till lately, the condition of a private soldier, both in this country and on the Continent, was unfavourable for inspiring a love of the service in his mind. Obliged to be furnished with good clothing and to preserve a becoming appearance, that which remained of his scanty pay scarcely sufficed for procuring the food necessary for his support. In his barracks he was subject to numerous petty details of duty, which produced weariness and even disgust; and, at all times, to the restraints of discipline, which deprived him of the recreations enjoyed by other classes of men; while the barracks themselves were far from being healthy or even comfortable. These disadvantages are now, however, in a great measure removed; and the pay of the soldier suffices to afford him the means of obtaining the comforts of life in a degree at least equal to those which are enjoyed by an ordinary peasant or mechanic. With the improvement of his condition, a corresponding improvement in the character of the soldier has taken place: men of steady habits are induced to enlist, and officers are enabled to select the best among those persons who present themselves as recruits for the army.

The duties of the soldier are now rendered as little burdensome as is consistent with the good of the service; the regulations promulgated by the authorities prescribe that he shall at all times be treated with mildness and humanity, and the non-commissioned officers are required to use patience and forbearance in instructing the recruits in their military exercises. When breaches of discipline on the part of the soldier oblige a commander to order the infliction of punishment, attention is paid as much as possible to render it a means of promoting a reformation of character: the lash is now very sparingly used. Wherever a regiment be now quartered, there is established for the soldiers a school, which the men are obliged, as part of their duty, to attend, and which is generally furnished with a library for their use. The library and school are formed and supported by the subscriptions of the officers, and both have been found to contribute greatly to the preservation of sobriety and good conduct among the men, by weaning them from the haunts of idleness and dissipation, and giving them a taste for useful knowledge.

In time of peace the soldier, being surrounded by the members of civil society, must, like them, conform to its laws; and, being under the influence of public opinion, he is, unconsciously to himself, held in obedience by them; so that no extraordinary coercion is necessary to keep him within the bounds of civil or military law. But in the colonies the soldier, even though he be serving in a time of peace, has many temptations to fall into a neglect or breach of discipline: he is far removed from the friends of his early life, who may have exercised upon his mind a moral influence for good: he sees around him only the conduct, too frequently licentious, of the lower orders of people in the country where he is stationed; and it may be that he is not fortified with the principles which should have been implanted in his mind by a sound education. The probability of a return to his native land before many years have passed is small, and the diseases to which he is exposed from the unhealthiness of the climate frequently terminate fatally: hence he becomes reckless from despair, and the facilities with which wine or spirituous liquors may often be obtained lead him into excesses which, while they accelerate the ruin of his health and render him unfit for duty, cause him to commit offences both against discipline and morals. Thus in the colonies there arises a necessity for greater restraints on the freedom of the soldier, and for the infliction of heavier punishments than are required at home. (Maj.-Gen. Sir Charles Napier, 'Remarks on Military Law.') Lastly, in time of war and on foreign service a vigorous discipline is essentially necessary; the privations to which soldiers are then exposed strongly induce those who are not thoroughly imbued with moral and religious principles to plunder the country-people, in order to supply their immediate wants, or to drown the sense of their sufferings in liquor.

SOLECISM (*soloecismus, σολοικισμός*), a grammatical term which is used by the later Greek and Roman writers, and by modern grammarians also, though in a somewhat different sense. It is defined by Sinnius Capito (Gell., v. 20) as an unequal and improper arrangement of the parts of speech, that is, as a violation of the rules of syntax. Quinctilian (i. s. 28, &c.) specifies four kinds of solecisms: the first consists in the addition of a superfluous word; the second, in leaving out one that is necessary; the third, in perverting the order of the words of a sentence; and the fourth, in using an improper form of a word. The ancients also used the word in a wider sense, understanding by it any kind of fault, error, or mistake, whether made in speaking, writing, or acting. Modern grammarians designate by solecism any word or expression which does not agree with the established usage of writing or speaking. But, as customs change, that which at one time is considered a solecism, may at another be regarded as correct language. A solecism therefore differs from a barbarism, inasmuch as the latter consists in the use of a word or expression which is altogether contrary to the spirit of the language, and can, properly speaking, never become established as correct language.

SOL-FA-ING. [SOLMISATION.]

SOLICITOR. [ATTORNEY; SIX CLERKS.]

SOLID, SOLIDITY. (Mechanics.) A solid body is one which is composed of matter so connected together that the relative positions of its parts cannot be altered without the application of sensible force. The force which resists the alteration of the relative positions is called force of cohesion [ATTRACTION]: the perfect absence of this force constitutes fluidity [FLUID].

SOLID ANGLE, a name given to the idea of opening conveyed by three planes which meet at a point. The properties of a solid angle are considered under the head SPHERICAL TRIANGLE.

SOLID, SURFACE, LINE, POINT. (Geometry.) We have thought it best to bring together the remarks which it is necessary to make upon these fundamental terms of geometry. According to Euclid, a point has no dimensions; a line, length only; a surface, length and breadth; a solid, length, breadth, and thickness. No one has the least doubt about each of these terms representing a clear and distinct notion already in the mind; in spite of this, however, the propriety of the definitions has been made matter of much discussion.

Space being distinctly conceived, parts of space become perfectly intelligible. Hence arises the notion of a boundary separating one part of space from the rest. That a material object, a desk or an inkstand, occupies a certain portion of space, separated by a boundary from all that is external, needs no explanation: this boundary is called surface, and possesses none of the solidity either of the desk or inkstand, or of the external space. Surface itself, when distinctly understood, is capable of division into parts, and the boundary which separates two parts of a surface has none of the surface, either on one side or the other: it therefore presents length only to the imagination. Again, length itself is capable of division into parts: the boundaries do not possess any portion of length, either on one side or the other: they are only partition marks or points. Euclid reverses the order of our explanation, requiring first the conception of a point, then of a line, then of a surface, then of a solid.

That when we think of a point, we deny length, breadth, and thickness; that when we think of a line, it is length without breadth that we figure to ourselves; that in the same manner the surface of our thoughts possesses no thickness whatever—are, to us at least, real truths. We cannot, for instance, imagine what Dr. Beddoes meant when he said ('Obs. on Demonstrative Evidence,' p. 33), "Draw your lines as narrow as you conveniently can, your diagrams will be the clearer; but you cannot, and you need not, conceive length without breadth." *Why* are diagrams the clearer, the narrower the lines of which they consist? Diagrams have no clearness in themselves; the comprehension of them is in the mind of the observer. If diagrams having (so called) lines of one-hundredth of an inch in breadth be clearer than others of five-hundredths of an inch, it is because the former approach nearer than the latter to a true representation of that which is in the mind, or of that which the mind desires to see portrayed. If the smaller the breadth the better the diagram in the clearness which it gives to the mind, it must be because the mind would have no breadth at all.

It matters nothing that the point, line, and surface are mechanical impossibilities; that no point or line, if they actually existed, could reflect light to show them; and that no surface could continue to exist for any perceptible time, even supposing it to have one moment of existence. Neither does it signify whether the ideas be necessary, or acquired from the senses; the question in geometry is, Have you got them? not, How did they come? There may be danger that some students should need at first to be frequently reminded of the abstract limits of which the conceptions must be made permanent, lest they should accustom themselves to rest in the imperfect approaches to these conceptions which are realised in their diagrams; but it is always found that a moment's recollection will produce a satisfactory answer to any question upon this point.

There is, it is true, one circumstance in which the pupil may acquire a permanently false notion of the object of geometry. If an instructor should require what is called a very well-drawn figure in every case, with very thin *lines* and very small *points*, he may perhaps succeed in giving the learner some idea that geometry consists in that approach to accuracy which constitutes practical excellence in the applications of the science. No idea can be more false: let the good line be examined under a microscope, and it is seen to be a solid mound of black lead or ink, as the case may be. Hence it is perhaps desirable that the demonstrations should be frequently conducted with what are called ill-drawn figures, in order that no reliance may be placed on the diagram, further than as serving to remind the student of the ideal conception which is the real object of his demonstration. This of course is recommended without prejudice to his learning the accurate use of the ruler and compasses for another distinct purpose, namely, the intention of producing *avowedly* approximate practical results.

It is to be noted that these definitions, so called, are in Euclid more than definitions. They appeal to conceptions supposed to exist, in words which are considered sufficient not to give, but to recall, the necessary ideas. This they actually do, to the satisfaction of the learner, who would never dream of their containing anything dubious, if it were not for the ill-advised interference of the psychologist. Whatever of pleasure or profit there may be in the subsequent union of the sciences, there is, we think, no doubt that the young geometer should not be required to examine the foundations of his notions of space: he cannot do this with effect until he has seen what these notions are by the light of their geometrical consequences.

SOLID, SUPERFICIAL, AND LINEAR DIMENSIONS. A solid, a surface, and a line, when they come to be the objects of arithmetic, are things as distinct as a weight and a time. That a surface is included by lines, or a solid by surfaces, makes no more of necessary connection between them than exists between weight and time, because the former can never be made sensible without the latter. Length only can measure length, a surface only a surface, a solid only a solid. Reasons of arithmetical convenience, not of necessity, make it advisable that whatever length may be chosen to measure length, the SQUARE on that length should be the surface by which surface is measured, and the CUBE on that length the solid by which solidity is measured. Unfortunately, if a foot be the measure of length, the square on a foot and the cube on a foot have no other names than *square foot* and *cubic foot*. The farmer with his acres, and the distiller with his gallons, have an advantage which is denied to the young mathematician. Ask the first how many acres make a gallon, and the second how many gallons make an acre, and both would laugh at the question; the third is allowed an indistinct conception of measuring surfaces and solids in feet or inches, as if they were lines, from the occurrence of the same word in all his measures.

Length is said to be a quantity of one dimension, surface of two, and solidity of three. The right line, the right surface or RECTANGLE, and the right solid or rectangular PARALLELOPIPED (the figure of a box, a die, a plank, a beam, &c.), are the implements of mensuration. Every surface must be reduced to the second form, and every solid to the third, before it can be measured. The rules (which tacitly contain these reductions) for measuring different superficial or solid figures will be found under the several heads: the two fundamental theorems by which measurement becomes practicable are as follows:—

1. The numbers of linear units in the two sides of a rectangle being multiplied together, give the number of superficial units, square units, or squares on the linear unit, which the rectangle contains. Thus a rectangle of 2½ by 4⅓ feet contains $\frac{5}{2} \times \frac{13}{3}$, or $\frac{65}{6}$, or 10⅚ *square* feet.

2. The numbers of linear units in the length, breadth, and thickness of a right solid, being multiplied together, give the number of solid units, cubic units, or cubes on the linear unit, which the right solid contains. Thus a plank of 2¼ inches broad, 1½ inch thick, and 10⅓ inches long, contains $\frac{9}{4} \times \frac{3}{2} \times \frac{31}{3}$, or $\frac{279}{8}$, or 34⅞ *cubic* inches.

SOLIDIFICATION. If heat be abstracted in sufficient quantity from a body in the liquid state, it will become solid. This change in the case of water is termed *congelation*. During solidification, the heat of liquefaction becomes apparent, as explained under LATENT HEAT. Certain liquids, however, have not been solidified at so low a temperature as −166° Fahr., such as alcohol, ether, and some others, noticed under GASES, LIQUEFACTION OF, where will be found a list of those gases which have been solidified under cold and pressure.

SOLIDITY. For the signification of this word in its strictest sense the reader is referred to IMPENETRABILITY; but, as the word is frequently employed to designate a condition of material substance in contradistinction from liquidity, or a gaseous form, it may in this sense be defined to be a state of a body in which the force of cohesion between the molecules is such that these require a certain amount of force to separate them from one another; and, at the same time, they are subject to small variations only of their mutual distances by the application of any quantity of heat less than that which would reduce them to ashes or convert them into fluids. The expansion of solids by heat is noticed under HEAT; see also SPECIFIC HEAT.

SOLIDS, REGULAR. [REGULAR FIGURES.]

SOLITARIUS (the Hermit), an obscure constellation of Lemonnier, which, having been admitted into the Astronomical Society's lists, appears here. It is situated a little above Centaurus, near the tail of Hydra. There are no conspicuous stars in this constellation.

SOLMISATION, or *Sol-fa-ing*, in singing, is the art of applying to the seven notes of the scale certain syllables, having no meaning in themselves, but containing the first five vowels, according to the French method, and the first four according to the system adopted by the Italians and English.

This art was practised by the Greeks; but the six syllables now in use are generally attributed to Guido d'Arezzo. These he selected, on account of their furnishing all the vowel sounds, from the following stanza of a monkish hymn to St. John the Baptist:—

> "*Ut* queant laxis,
> *Re*sonare fibris
> *Mi*ra gestorum
> *Fa*muli tuorum
> *Sol*ve polluti
> *La*bii reatum.
> SANCTE JOANNES."

In what is called the hexachord system [HEXACHORD], these syllables were found sufficient. When, however, that absurd method began to be disused, the addition of a name for the seventh of the scale became necessary, and Le Maire, a French musician of the 17th century, has the credit of having introduced for this purpose the syllable *si*. The Italians rejected the French *ut*, and substituted the more euphonous syllable *do*, which is also adopted in England. The syllables therefore now used by the Italians and English are as follows:—

Do,	Re,	Mi,	Fa,	Sol,	La,	Si,	Do.
C,	D,	E,	F,	G,	A,	B,	C.

To these syllables the English give the Italian pronunciation.

SOLOMON, THE SONG OF, or THE BOOK OF CANTICLES (שִׁיר חַשִּׁירִים; *Ἆσμα τῶν ᾀσμάτων*, 'Canticum Canticorum,' our 'Song of Songs') a canonical book of the Old Testament.

The canonical authority of this book has been much disputed. It is now admitted that it formed part of the Jewish canon. It is found in the oldest Christian catalogues of the sacred books, and in all the ancient versions, though it is not quoted in the New Testament. The objections to its canonical authority are now therefore derived solely from its internal character, and may be summed up in the following argument: that the book cannot form a part of Holy Scripture, since it contains no religious truth, unless we interpret it after a fashion for which there is no authority.

The book is a poem, or collection of poems, describing in imagery which is certainly warm, but to an oriental taste perfectly delicate, the chaste loves of a bridegroom and his bride. It bears the name of Solomon in its title, 'The Song of Songs, which is Solomon's;' and is supposed to be the only remaining one of the thousand and five songs which we are told that that monarch composed. According to the common opinion it was composed as an epithalamium at the marriage of Pharaoh's daughter with Solomon, who are respectively the bride and bridegroom of the poem; but under the guidance of divine inspiration it was so constructed as to form a mystical allegory representing the relation between Christ and his church.

First, then, with respect to its date and author. An attempt has been made, supported by Kennicott, Eichhorn, Jahn, and Rosenmüller, to prove the poem later than the Babylonish captivity, but Ewald, an excellent judge, and De Wette, agree in referring it to the time of Solomon. The style and language are not more different from that of the 'Book of Proverbs' than might be expected from the difference of the subjects. But the structure and contents of the poem are alleged as presenting insuperable obstacles to the supposition that Solomon was the author. Again, with reference to the bride, it is contended that the poem itself proves her to have been not an Egyptian princess, but an Israelite. This point is very strongly brought out by Dr. Mason Good. On all these points the difficulty is much increased by the highly coloured imagery of the poem. But the first difficulty may perhaps be explained by supposing one or more changes of scene: there seem in fact to be several. The question respecting the person designed to be represented by the bride, it has been attempted to solve in various ways. Dr. Mason Good imagines that the poem describes a *love-match* which Solomon made with some Israelitish woman after his *political* marriage with Pharaoh's daughter. A third mode of explanation, which if adopted would cut the knot, is that of Dr. James Bennett, who supposes that the poem never had any literal reference at all to an actual marriage, but is purely an allegory descriptive of the mutual love of Christ and his church. But the minute allusions, especially those to Solomon, which are contained in this poem, are a most formidable objection to such an explanation; and even those critics who contend most strongly for the purely allegorical character of the 45th Psalm, maintain as strongly that the Song of Solomon has a literal as well as a spiritual meaning. (See especially Bishop Horsley's 5th 'Sermon.') The distinction however between the two questions of who was the author and who were the parties described, ought not to be lost sight of, as it too often has been. Finding the book in the Jewish canon, the presumption is that it is a genuine part of Holy Scripture, and is intended to teach religious truth. This presumption is strengthened, if it can be proved that Solomon was the author, since we have at least one other book of his in the sacred canon; but it is not disproved even if the poem should be found to have nothing to do with Solomon either as its author or its subject.

It is admitted that from a very early period the oriental nations have been accustomed to express religious sentiments allegorically under the guise of amatory poems, of which the Gitagovinda is an example. To this day the Egyptian Arabs, at their religious festivals, sing songs resembling this, in which the prophet is the beloved object, and which are only intended to have a spiritual sense. (Lane's 'Modern Egyptians,' vol. ii.) Mr. Lane in fact gives passages from these songs strikingly parallel to passages in Solomon's Song. Neither is it denied that similar imagery is used with a similar meaning in other parts of the Bible (Psalms, xlv.; Isaiah, liv.; lxii. 4, 5; Rom., vii. 4; 2 Cor., xi. 2; Ephes., v. 23–32; Rev., xix. 7; xxi. 2–9), and also the opposite figure of representing idolatry and apostacy under the image of adultery or whoredom. But it is said that in all such passages the allusions are more distant, and enter less into detail than is the case in Solomon's Song, and that in them the religious sense is made so prominent that one can scarcely fail to perceive it. The first part of this assertion does not appear to be sustained by fact. Any one who examines the passages carefully, especially those which relate to spiritual adultery, will find allusions inferior in delicacy to the grossest which can be produced from Solomon's Song. The latter condition does not appear to be necessary (as has been argued above) to establish the allegorical meaning of such imagery, when occurring in a canonical book: neither is the spiritual sense always so obvious. For example, there is nothing in the 45th Psalm, except one or two expressions which could not by the greatest hyperbole refer to a human being, to lead us to suspect its spiritual meaning. The fact that the 45th Psalm is quoted in the New Testament, and that the Song of Solomon is not so quoted, is no objection to this view of the subject, for the quotation of the one sanctions the general principle of interpretation, while the silence respecting the other proves nothing, knowing as we do that the New Testament writers adopted the Old Testament canon as it existed in their day, and that this Song was in that canon. Nearly all expositors, both Jewish and Christian, have adopted the allegorical interpretation, though they have explained the allegory in different ways. The Chaldee Targum considers it as a figurative description of the love of God to Israel, as shown in delivering them from the Egyptian slavery, supporting and comforting them in the wilderness, and bringing them into the promised land. Christian expositors, from Origen downwards, have generally understood it as descriptive of the union between Christ and the church; but some few have explained it in a different way. Those who acknowledge its canonicity, but reject the idea of a reference either literally to Solomon or figuratively to Christ, take its admission into the canon to be a divine recommendation and praise of a single virtuous marriage as opposed to polygamy and concubinage. This was latterly the opinion of the most distinguished modern opponent of its canonicity in England, Dr. J. Pye Smith. Various opinions are held as to the structure of the Song, the best of which appears to be that which takes it to be a pastoral-nuptial song in a dramatic form.

(The *Introductions* of Eichhorn, Augusti, Jahn, and Horne; *Papers* by Dr. Smith, Dr. Bennett, and others, in the 'Congregational Magazine' for 1837 and 1838; *The Song of Songs*, by Mason Good, Lond., 1803; other *Commentaries* in Horne, vol. ii., part ii.; Lowth's *Prælections;* Hirzel, *Das Lied der Lieder, oder Sieg der Treue*, Zurich, 1840; Fava, *La Cantica delle Cantiche*, Milano, 1840.)

SOLOMON, THE WISDOM OF (*Σοφία Σαλώμων*), an apocryphal book of the Old Testament, ascribed to Solomon, but manifestly written long after his time. It is not known to have ever existed in Hebrew, and it contains Greek ideas and expressions which prove it to belong, if to a Jew at all, to one of the Alexandrian school. There are in it historical references utterly at variance with the state of things in Solomon's reign, and quotations from Isaiah and Jeremiah. Internal evidence would point to the end of the second or beginning of the 1st century B.C. as the time of its composition. It is commonly ascribed to Philo the Jew, but the style is quite different from his genuine writings. It was badly translated into Latin before the time of Jerome, who did not revise the version. The fathers of the church considered it apocryphal; but it was pronounced canonical by the third council of Carthage (A.D. 397), and again by the council of Trent.

It consists of two parts. The first part (chap. i.–ix.) contains the praise of wisdom, an exhortation to all, and especially to kings, to seek it, and the manner in which it is to be obtained. The second part (chap. x.–xix.) brings forward examples from history of the happiness that springs from wisdom and the misery entailed by folly. Throughout the book Solomon is represented as speaking; and the work is evidently an imitation of his proverbs. It is remarkable as being the earliest Jewish work extant which contains a clear statement of the doctrine of rewards and punishments in a future state.

SOLSTICES, the points of the ecliptic which are highest above the equator, at which, the sun's motion in declination being imperceptible, the days remain sensibly unaltered in length for several days together, as they would do if the sun absolutely stood still: whence the name. [SUN.]

SOLUBILITY. [SOLUTION.]

SOLUTION. When the force of ADHESION is exerted between a solid and a liquid with sufficient energy to overcome the cohesion of the former, the substance is said to be soluble, or to undergo solution, or to be dissolved. The solution of sugar in water, of resin in spirits of wine, of silver in mercury, is now regarded as a form of adhesion. Certain liquids are also soluble in other liquids, gases in other gases, and gases in liquids, as noticed under DIFFUSION. For the solubility of gases in liquids, we refer to GAS. In the present article we may give a few details respecting the solution of solids in liquids.

The liquid which effects the solution is usually termed the *solvent*, but sometimes the *menstruum*. Particular solutions have also special names, such as *syrup*, which is applied to the solution of sugar in water, while *tincture* refers to a solution of a solid in alcohol. When a liquid can no longer dissolve further portions of the solid, it is said to be *saturated;* that is, the force of cohesion balances that of adhesion. Generally, however, an elevation of temperature, by diminishing cohesion, will increase the solvent powers of the liquid. But there are cases in which cold appears to favour solution: thus lime and some of its salts dissolve more readily in water just above the freezing-point than when boiling. Crystallised sulphate of soda requires about ten times its weight of ice-cold water for solution, and its solubility increases rapidly with the temperature up to 91° Fahr., from which point up to the boiling-point of the solution the solubility decreases; and the liquid, saturated at 91°, deposits a portion of the salt by increasing the temperature. Seleniate of soda and sulphate of iron afford similar results, which are due probably to the fact that heat diminishes adhesion as well as cohesion, but the former force decreases more rapidly than the latter. If a liquid added to a solution have a stronger adhesion to the solvent than to the substance dissolved, the latter will often be thrown down in a pulverulent state: thus, the addition of water to camphorated spirit will throw down camphor.

Solution is favoured by increasing the extent of surface in the solid, as by reducing it to powder. In general, the first portions of a solid disappear rapidly, and the after portions more and more slowly until saturation is reached. Solids present innumerable degrees of solubility; for while some bodies, such as sulphate of baryta, are almost insoluble, and sulphate of lime only soluble in about the proportion of 1 part in 700 parts of water, 1 part of sulphate of potash will dissolve in 16 parts of water, and 2 parts of sulphate of magnesia will dissolve in only 3 of water. It is remarkable that water saturated with one salt will dissolve others. As aqueous solutions of solids are heavier than water, the degree of solubility of a solid may be judged of by suspending it in a glass of water, and watching the current as it descends. "If it fall rapidly, and in dense striæ, it will indicate rapid solubility, and the formation of a dense solution; if it fall in a very narrow stream, it will indicate only moderate or slight solubility; and by its descending rapidly or in a slow broad stream, or by resting about the substance, a judgment may be made of the comparative density of the solution produced. If no descending current appear, nor any fluid round the substance of a refractive power or colour different to that of the water, then the body must be very nearly, if not quite, insoluble at common temperatures." (Faraday, 'Chemical Manipulation.') The taste will also frequently give an indication of the solubility of a solid.

In general, a solution due to adhesion partakes of the properties both of the solvent and of the substance dissolved. Where chemical change intervenes, we have the properties of a third body. Hence, in cases of simple solution, the solvent and the body dissolved have, to some extent, properties in common, as when mercury dissolves many of the metals, and oils dissolve fatty bodies and each other; but in cases of chemical action, the affinities are strongest between bodies the most dissimilar, as when the acids dissolve metals or their oxides, oils the alkalies, and so on.

The uses of solution are numerous. It allows a body to be purified by filtration or crystallisation, so that one substance may be separated from another, either by crystallisation or by the use of such fluids in succession as have a solvent power over one or more of the substances present. By means of solution, substances are prepared for the exertion of chemical action, and all obstructions due to the attraction of aggregation removed.

SOLUTION. (Mathematics.) By the solution of a problem should be meant the method of finding that which the problem requires to be found: but the word is frequently understood to apply to the answer itself.

A solution is given when the problem is reduced to any other which was supposed to be known before the first was presented: the difficulty peculiar to the given problem is removed as soon as it is shown to be capable of reference to another and a lower class. Thus, though properly speaking a problem is not solved until the answer is presented in numbers, yet it is not thought necessary to require that such a result should be attained, provided the steps which are left are such as are well known and generally admitted. Thus an equation would be said to be solved were it found that the roots required are those of a given quadratic; for no one is supposed ignorant of the mode of then finding them.

A *geometrical* solution, in the strict sense of the word, is one in which only the means of construction admitted by Euclid, or others deducible from them, are employed in its attainment. This is the least finished of all solutions; for a mode of laying down the various points which terminate lines is not, generally speaking, a mode of ascertaining the ratio of these lines. Nor must it be forgotten by the admirers of geometry that the most important part of a result, the expression of the ratios which the answer bears to the several data, is only indirectly obtained in their favourite method.

When more means than those allowed by Euclid are employed, the solution used to be called *mechanical*. It is rarely that such a solution is now employed.

An algebraical solution is one which employs algebra and arithmetic, to the exclusion of geometrical construction; that is, one in which the answer can always be directly calculated from a formula. Geometrical construction may be necessary for the demonstration of the solution: it is enough that the answer contain no directions to find lines or surfaces by construction.

An approximate solution is one which has an amount of inaccuracy necessarily. Thus if $3 + \sqrt{2}$ were the root of an equation, this solution would not be called approximate; for though $\sqrt{2}$ cannot be perfectly represented in a finite form, the symbol itself contains the mode of attaining the result with any degree of exactness short of perfection. But if $\sqrt{2}$ were found to five decimal places, the answer 1·41421 would be called an approximate answer. Most solutions must terminate in an approximate representation. [TRANSCENDENTAL.]

SOLVENT. [SOLUTION.]

SOMNAMBULISM, a word of modern origin, which means strictly and etymologically *sleep-walking;* it is however generally used in a more extended signification to comprehend all the phenomena that take place when a person, apparently insensible to external objects, acts as if he were in a state of consciousness: and this is the sense which the word will bear in this article. M. Bertrand, in his 'Traite du Somnambulisme' (8vo., Paris, 1823), divides those phenomena into four classes: 1, essential (or *proper*) somnambulism, which arises from some particular disposition of the nervous system in persons who in other respects apparently enjoy perfect health; 2, symptomatic (or *morbid*) somnambulism, which occurs in the course of certain diseases; 3, artificial somnambulism, which is occasioned by the proceedings employed in animal magnetism or mesmerism; and, 4, ecstatic somnambulism, which is the result of a sort of religious enthusiasm. The same division of the subject will be here adopted.

I. *Essential* (or *Proper*) *Somnambulism* is intimately connected with the subject of sleep and dreaming; and in fact "a somnambulator," as Dr. Pritchard says, "is nothing but a dreamer who is able to act his dreams." [DREAMS.] [SLEEP, in NAT. HIST. DIV.] As a minute inquiry into the physiology of these two phenomena would here be out of place, the reader must consult the articles already given on these subjects. This form of somnambulism was noticed by the ancients. The author of the treatise 'De Morbo Sacro,' that commonly goes under the name of Hippocrates, says that "he knew many persons who used to groan and cry out in their sleep, and others that seemed to pant for breath (*πνιγομένους*), and others that would get up and run out of the house and act like madmen till they were awakened, after which they were in good health and sound sense as before, only rather pale and weak" (tom. i., p. 588, ed. Kühn). Aristotle tells us that "there are individuals who rise in their sleep and walk about, seeing as clearly as those that are awake." Diogenes Laertius mentions ('De Vitis Philosophorum, Pyrrho,' lib. ix.) that a Stoic philosopher named Theon was a sleep-walker; and Galen says ('De Motu Musculorum,' lib. ii., cap. 4, tom. iv., p. 435, 436, ed. Kühn) that he would not believe that people ever fell asleep while walking, until one night when walking along the road he did so himself, and went on for about a furlong, sleeping and dreaming, till at last he was awakened by kicking against a stone. "And this," adds he, "is the reason why people cannot go on walking for any distance in their sleep, because they cannot meet with a perfectly smooth road;" in which he is not quite correct, as we often find that both the bodily and intellectual powers of the individual are more active and developed in his sleep then when he is awake, and that he is then able to perform feats which at any other time he would shudder at. The instances on record of this species of somnambulism are so numerous that it is difficult to select the most interesting; one or two examples however must be given, and for a more copious collection the reader must be referred to some of the works whose titles will be given in the following part of this article.

Several interesting cases of somnambulism will be found in Muratori's work, 'Della Forza della Fantasia Humana;' some of them given on the authority of Gassendi. One of Gassendi's somnambulists used to rise and dress himself in his sleep, go down to the cellar and draw wine from a cask. He appeared to see in the dark as well as in a clear day; but when he awoke, either in the street or cellar, he was obliged to grope and feel his way back to his bed. He always answered his wife as if awake, but in the morning recollected nothing of what had passed. Another sleep walker, a countryman of Gassendi's, passed on stilts over a swollen torrent in the night, but on awaking was afraid to return before daylight, or until the water had subsided. This species of somnambulism has been known to be hereditary. Horstius, in his work 'De Natura, Differentiis, et Causis eorum qui Dormientes ambulant' (seu 'de Noctambulonibus'), Lips., 1595, 8vo., p. 172, mentions three brothers who were affected with it at the same time; and Willis knew a whole family that was subject to it. Perhaps however these may rather be considered as instances of the influence of example and of the power of unconscious imitation, which sometimes renders it in a manner contagious. Of this there is a curious example given by Dr. Pezzi, in a work entitled 'Scretti di Medico Argomento,' Venez., 1813. It appears that his nephew, after reading more than once the history of a somnambulist, was himself seized with this affection; and also that the servant who attended him soon began to exhibit in his own person similar phenomena.

Essential somnambulism occurs in many persons (says Dr. Good) without any manifest predisponent cause, though it is generally connected with a considerable irritability of habit. A morbid state of the stomach, where this habit exists, has very frequently proved an exciting cause; and where this is the case, the attention of the physician must of course be directed to that quarter. With respect to the mode of treatment during the fit, though it has sometimes been recommended to employ violent means, so as to awaken the somnambulist suddenly, and to repeat this as often as the attacks come on, until they have completely ceased; yet M. Bertrand warns us against such a proceeding. "If, in the first place," says he, "sensibility is completely extinguished, all the means employed to awaken the somnambulist will be useless; secondly, even when it is possible to awaken him at once, the sudden shock produces serious consequences; thirdly, as somnambulism is often the result of a salutary crisis of nature, one is never sure of not hurting the patient by suppressing it; and, lastly, the sudden suspension of habit of the animal economy that has been contracted for a long time, must in all cases be attended with danger." He adds that the best plan is to try to put oneself in connection with the patient by entering into the course of ideas by which he is occupied during the attack, and so endeavour to direct him in a reasonable manner.

II. *Symptomatic or Morbid Somnambulism* generally presents itself as one of the phenomena attending catalepsy. [CATALEPSY.] This form of somnambulism does not appear to have been noticed by the ancients; but there are many cases on record long before the time of Mesmer, as well as others described by persons unacquainted with and even opposed to the doctrines of animal magnetism. The following case is given by Colquhoun, on the authority of Sauvages, and may be found in greater detail in the 'Hist. de l'Académie des Sciences,' for the year 1742: A girl of twenty years of age was frequently attacked with cataleptic insensibility, during which she continued stiff and deprived of all sensation, whether standing, sitting, or lying, in the position she might happen to be in at the time of the commencement of the attack, and she could be pushed forward, like a statue, when it was wished to remove her from one place to another. She was afterwards placed in a different state, which commenced with the same deprivation of sense and motion, but at intervals presented a wonderful kind of animation. She first became motionless, then, some minutes afterwards, she began to yawn, sat up on the bed, and enacted the following scene, which she repeated at least fifty times. She spoke with an unusual liveliness and cheerfulness, and what she said was a continuation of what she had spoken in her previous fit, or a repetition of some part of the catechism which she had heard read on the preceding evening. She frequently addressed her acquaintances in the house, and sometimes made ironical applications of moral apophthegms to them under feigned names with open eyes, and such gestures as she had made the previous evening. That during all this time she was not awake, was clear from various experiments. A hand was suddenly passed near her eyes, without producing any motion in the eyelids or any attempt to evade it, or interrupting her speech in the slightest degree. The same thing happened when a finger was suddenly approached close to her eye, or a burning taper held so near to it that the hair of her eyelids was actually burnt, and also when any one called loudly into her ear from behind, or threw a stone against the bedstead. Nay more, brandy and spirit of hartshorn were poured into her eyes and mouth; Spanish snuff was blown into her nostrils; she was pricked with needles; her fingers were wrenched; the ball of her eye was touched with a feather, and even with the finger: yet she manifested not the slightest sensation. During these trances she always began to speak with more than usual animation; soon afterwards, she sang and laughed aloud, attempted to get out of bed, and at length sprang out of it and uttered a cry of joy. She kept the middle way between the bedsteads as well as when awake, and never came against them—turned dexterously round between the bedsteads and a concealed closet, without ever groping her way or touching the objects; and after turning round, she returned to her bed, covered herself with the clothes, and again became stiff as at the commencement. She then awoke as if from a profound sleep, and when she perceived, from the appearance of the bystanders, that she must have had her fits again, she wept the whole day for shame, and never knew what had happened to her during the paroxysm. The above is by no means one of the most wonderful cases of somnambulism occuring during a cataleptic seizure, but it has been chosen on account of the respectable authority on which it rests. Those recorded by M. Petetin ('Mémoire sur la Découverte des Phénomènes que présentent la Catalepsie et le Somnambulisme, &c.,' 1787; and 'Electricité Animale prouvée par la Découverte des Phénomènes Physiques et Moraux de la Catalepsie Hystérique, et de ses Variétés,' Lyon, 1808), are not perhaps less authentic.

III. *Artificial Somnambulism*, or that which is occasioned by the proceedings employed in animal magnetism, is not expressly mentioned by any ancient writer, but some lines by Solon, and a verse in Plautus ('Amphitr.' i. 1–157) have been supposed by some persons to allude to these manipulations. As an account of the doctrines of Mesmer has been already given under the head of ANIMAL MAGNETISM, it will be sufficient here to refer to the 'Rapport sur les Expériences Magnétiques faites par la Commission de l'Académie Royale de Médecine [à Paris], lu dans les Séances des 21 et 28 Juin, 1831, par M. Husson, Rapporteur.'

With respect to the phenomenon of somnambulism as caused by mesmerism, or animal magnetism, so much credulity and deception have been brought to light in connection with it, that a person cannot be too cautious in sifting and weighing the evidence on which each of the alleged instances rests; but after all this mass of knavery and folly has been cleared away, there still remain a large number of instances which cannot be disbelieved without discarding all historical evidence whatever. For more information on the subject the reader may consult, besides the works already quoted, the Rev. Chauncey Townshend's work on Somnambulism, and 'Le Magnétisme Animal en France,' by M. Bertrand, Paris, 1826.

IV. *Ecstatic Somnambulism.*—M. Bertrand has given this name to that species which is produced by a high exaltation of the mind, and becomes in a manner infectious by sympathy in such persons as are predisposed and subjected to the same influences. Of this last species, the *devotional ecstasis* is perhaps the most frequent and the most remarkable; and this has been supposed to have had some connection with the oracles and other miraculous stories of antiquity. M. Bertrand has, however, for obvious reasons, selected his instances from four different periods in modern times, in each of which the devotional ecstasis appeared as a sort of epidemic, and presented symptoms very similar to those occurring in the three former species of somnambulism. The first series of phenomena are those which took place in connection with the burning of the unhappy Grandier on the charge of sorcery at Loudun, in 1634, an account of which may be found in Bayle ('Dict. Hist.,' art. 'Grandier'); or in the 'Hist. des Diables de Loudun,' by a Protestant Refugee, Amst., 1693, 12mo. The next instances are extracted from a scarce work entitled 'Théâtre Sacré des Cévennes,' and relate to the French Protestants who, after the revocation of the Edict of Nantes, 1685, went by the name of the 'Trembleurs des Cévennes,' and were persecuted and massacred in those mountains. The third epidemic broke out at the tomb of the Abbé Pâris in the church of St. Médard, at Paris, about the year 1731. These are perhaps the most celebrated of all, as having been selected by Hume to oppose to the miracles of the New Testament. The original and authentic account of them was published by M. Carré de Montgeron, in a work entitled 'La Vérité des Miracles opérés à l'Intercession de M. de Pâris,' &c., 2 vols. 4to, 1737, 1741; and they are examined at some length and with great acuteness by Bishop Douglas, in his 'Criterion, or Miracles Examined,' &c. To these he has added, fourthly, some considerations on the state produced in the patients who, towards the end of the last century, were exorcised by a priest named Gassner, at Ratisbon. An account of these (supposed) miraculous cures is to be found in a work entitled 'L'Antimagnétisme; ou Origine, Progrès, Décadence, Renouvellement, et Réfutation du Magnétisme Animal,' 8vo, Londres, 1784 (pronounced by M. Deleuze to be the ablest publication that had appeared against the doctrines of Mesmer), which account is extracted from a work called 'Procès-verbal des Opérations Merveilleuses, &c., par le Ministère du Sieur Gassner,' &c., Schillingsfürst, 1775. As, however, neither these nor many other examples that might be brought forward can be fully noticed here, it has been thought sufficient to point out the places where further information may be procured.

SONG, a term applied to either a short poetical or musical composition, but most frequently to the two in union.

As denoting a musical composition, *song* is used, in this country, to signify a vocal melody of any length or character, and not confined to a single movement; and while the solemn air of the oratorio, and the *aria grande* of the Italian opera, are frequently, though erroneously, called by this name, the same is bestowed on the short, simple ballad. But this is only one instance among many of the defective state of our musical nomenclature. Of the varieties of *song*, see AIR, BALLAD, CANZONET. The term however is not absolutely unlimited in its meaning, for, as regards performance, it is most frequently confined to an air for a single voice. Thus our composers, especially in the 16th and 17th centuries, often entitle their productions for more than one voice, 'Part-Songs.'

Concerning the *songs*, or *Σκόλια*, of the Greeks, see Music and Scolia. Of the Roman song, musically considered, we are without information. Having more of war than of taste in their nature, the Romans bestowed little thought on music, and coldly adopted what was transmitted by the elegant Greeks. But music, as the term is at present understood, is an art exclusively modern, and cannot be said to have existed till the invention, or at least the use, of counterpoint.

The poetry of modern songs has, in too many instances, degenerated, while the music of them has gradually improved. England, from about the middle of the last century till a recent period, furnished its full share of beautiful songs (this term excluding all airs of greater pretensions) to the general stock. France rather later began to contribute its fair quota; and however opinions may differ respecting the merit of earlier French melodies, it seems to be agreed that they may now compete with those of most other nations. But it must be admitted that Germany of late years has taken the lead in this, as in higher departments of music.

SONG OF SOLOMON. [Solomon's Song.]

SONNET (Italian, *Sonata*, *Sonetto*), a form of poetry much used by the Italian and Spanish poets, but which our deficiency of rhymes has caused to be more sparingly used in English. The sonnet properly consists of two quatrains, having properly but two rhymes, and two tercets. The last six lines are susceptible of various arrangements; the one usually adopted in English is the rhyming of the fifth and sixth lines together, frequently after a full pause, so that the sonnet ends with a point, as in an epigram. The Italians consider the best form to be the rhyming together of the three uneven and the three even lines; but our poverty of rhymes causes us to prefer the rhyming of the first and fourth, second and fifth, third and sixth lines: this, with a break in the sense at the third line, constitutes also a legitimate sonnet, of which the Italians have given abundant precedents. We need scarcely observe that all our poets have held themselves at liberty to vary the form of the sonnet. The lightness and richness of the Italian and Spanish languages enable their poets to express every feeling or fancy in the sonnet; but with us it has been found most suitable to grave, dignified, and contemplative subjects. Hence Milton and Wordsworth are our best writers of sonnets.

SONOROUS VIBRATIONS. When the air or other elastic body is made to vibrate with sufficient rapidity, *sound* is produced. [Acoustics.] During such vibrations the molecular arrangement of the sounding body becomes changed, but returns to its normal state when the vibrations cease. [Nodal Points and Lines.] It is stated (Bird's 'Natural Philosophy,') that if a copper ribbon 9 feet long, ·4 inch wide, and ·04 inch thick, be vibrated, its length will appear to be unaffected. If it be stretched by a weight of 90 lbs., its length will remain the same until it be made to vibrate, when it will become permanently lengthened by 6 or 7 inches. When sonorous vibrations are isochronous a perfect *sound* or *tone* is produced; when irregular, a *noise*. For the phenomena produced by the reflection of sonorous vibrations, see Echo, and for their interference Acoustics and Interference. For the production of sonorous vibrations during the cooling of heated metals, see Thermophone. For the different kinds of vibrations, see Vibrations.

SOOT is that portion of fuel which escapes combustion, and which is mechanically carried up and deposited partly in chimneys and partly in the air. The soot of coal and that of wood differ very materially in their composition; the former indeed does not appear to have been accurately analysed, but it evidently contains more carbonaceous matter than the latter. Coal-soot contains substances usually derived from the distillation of organic matters; it contains sulphate and hydrochlorate of ammonia, and has been used for the preparation of the carbonate; to hot water it yields a brown bitter extract, and it contains an empyreumatic oil; but its great basis is charcoal in a state in which it is capable of absorbing ammonia from the air, and hence with the ammoniacal salts it already contains, it is used as a manure, and acts very powerfully as such. Sir H. Davy observes that for this purpose it is well fitted to be used in the dry state, thrown into the ground with the seed, and requires no preparation.

The soot of wood has been minutely analysed by Braconnot, who found it to consist of the following substances:—

Ulmin (about)	30·20
Azotised matter	20·00
Carbonate of lime and traces of carbonate of magnesia	14·66
Water	12·50
Acetate of lime	5·65
Sulphate of lime	5·00
Acetate of potash	4·10
Carbonaceous matter insoluble in alkalies	3·85
Ferruginous phosphate of lime	1·50
Silica	0·95
Acetate of magnesia	0·53
Asbolin (a peculiar acrid and bitter principle) about	0·50
Chloride of potassium	0·36
Acetate of ammonia (about)	0·20
Acetate of iron (a trace)	..
	100·

Braconnot considers the ulmin as absolutely similar to that obtained artificially by the action of potash on wood-sawdust, but Berzelius is of a different opinion, and calls it *gein*. The azotised matter is very soluble in water, and insoluble in alcohol. As coal-soot contains much more carbonaceous matter than wood-soot, and also a much larger portion of ammoniacal salts, it must be more active as a manure, and altogether a more useful substance.

SOPHISM (*Σόφισμα*), that superficial and incomplete aspect of the truth, which at first sight looks like the truth, but on closer inspection turns out to contain some radical error. This seems the most correct definition, but the word is used loosely. Its general signification, namely, a *specious* proposition, is perhaps nearest the mark. Truly considered, most errors are sophisms, for errors are not direct contradictions to the truth, but simply the leaving out of view one or more elements of the truth, and seizing on only one or two elements, and declaring them to constitute the whole truth. Victor Cousin defines error to be "One element of thought considered exclusively, and taken for the complete thought itself. Error is nothing but an incomplete truth converted into an absolute truth." ('Introduction à l'Hist. de Philosophie,' Leçon 7.) Spinoza had before defined "falsity to be that privation of truth which arises from inadequate ideas." ('Ethica,' b. ii. prop. xxxv.) It is sometimes a mere confusion of terms; as in the common example of—Bread being better than paradise; because bread is better than nothing, and nothing is better than paradise—the confusion arises from both the "nothings" being used substantively; whereas it is only the first that is so used; the second is affirmative, and expresses "there is nothing better." A sophism is therefore the use of some word in a different sense in the premises from that in the conclusion, and this is the definition of Aristotle ('Top.' viii. 11): "When the discourse is a demonstration of anything, if it contain anything which has no relation to the conclusion, there will be no syllogism; and if there appear to be one, it will be a sophism, and not a demonstration."

This confusion of words and ideas is the origin of all errors and sophisms; but though errors and sophisms are logically constituted alike, yet the instinctive sense of mankind marks the difference between incomplete views (error) and wilful perversion (sophism). In all cases a sophism is supposed to be recognised as such by the sophist. It is an endeavour on his part to "make the worse appear the better reason." It is the consciousness then of the sophist which distinguishes and renders odious his error as a sophism.

SOPHISTS. The race of sophists took its rise in Athens about the 5th century B.C., when Athens was a real democracy. From the necessity every man was under of pleading his own cause before the dicastery, in any case before the court, whether as plaintiff or defendant; from the political power which every citizen possessed, but could scarcely exercise with effect unless able to speak fluently; the teaching of rhetoric, or the arts of speaking and arguing logically, came to be in much request. The age was also a sceptical, and therefore an investigating one. But though flourishing in Athens, sophists and their teachings were not confined to that city, but extended throughout all the Grecian republics, and occasionally to the courts of tyrants. They went about Greece discoursing and debating, and sometimes educating the youth of rich and noble families. They were not, strictly speaking, a sect; indeed the name signifying only a wise or clever man, had been so applied from the earliest times of Greece; and Socrates, Plato, and other eminent men were all called sophists.

The disrepute attached to the name arose apparently from the facts of the teachers accepting payment for their lessons, and thence proceeding to inculcate not the desire for truth, but the means of securing victory by the use of specious fallacies. It was against both these modes that Socrates and Plato contended; and to which Plato and Aristotle affixed the name as a term of reproach for a "man who employs what he knows to be fallacy, for the purpose of deceit and of getting money." (Grote, 'Hist. of Greece,' vol. v.) But the sophists were able to bear up against the judgment of philosophers, by having become the trainers of men for the active pursuits of life, and their influence over the multitude greatly exceeded that of the sages. Nor did they all, though they taught for money, teach fallacies merely; and the representations of them in the Dialogues of Plato must not be accepted as the truth with reference to them as a class. Socrates, Protagoras, and Prodicus, were stigmatised as sophists, but what we know of their doctrines and practice does not deserve any heavy condemnation. No doubt, in numerous instances the sophists, like the schoolmen of the middle ages, indulged in subtleties and evasions which were dishonest, trivial, and often ridiculous; but, as Ritter says ('Geschichte der Philosophie,' vol. i.), "It is not to be denied that the sophists contributed greatly to the perfection of prose; which was in itself a great benefit to philosophy. The sophists applied themselves to manifold arts of persuasion, and in their attacks upon each other, labouring to expose and lay bare the delusions of appearance, they acquired great nicety in the distinction of terms. Prodicus was celebrated for his skill in the distinctions of synonymous terms (as we learn from Plato, who ridicules him for it, (Protag. p. 337; Crat. p. 384); but Prodicus is honourably mentioned by him (Euthyd. p. 277-305). The sophisms turning upon the words 'to learn,' 'to understand,' 'to know,' also contributed to the more accurate knowledge of these terms. The very circumstance that their rules were intended to be subservient to the ends of fallacy and deception, must have afforded a stronger motive to the philosophical spirit to bring under investigation the true forms of thought and expression which had been neglected by earlier philosophers; and accordingly we find that they occupied much of the attention of Socrates."

SOPRA'NO (Italian), the highest of the various voices; the treble. [Voice.]

SORBIN. [Sugar.]

SORBINIC ACID. [Sugar.]

SORITES. A name given to any chain of premises, more than two in number, from which a conclusion follows. As, Every A is B, Every B is C, Every C is D, Every D is E, therefore, Every A is E.

SOTHIAC PERIOD. The ancient Egyptian year consisted only of 365 days, without any intercalation; and was divided into 12 months of 30 days each, with 5 days added at the end. (Herodotus, ii. 4.) The Scholiast on Aratus informs us that the priests were sworn never to alter this year. This oath, we may conjecture, only came into use after the discovery of the fact that a fraction of a day more would have been desirable to make the civil year conform to the sun. As long as 365 days was imagined to be the real year, it is not likely that they would have sworn each other to its observance; but if, after the discovery, a party were formed in favour of an alteration, the attempt to preserve the ancient institution by an oath would be almost a matter of course. Again, Diodorus Siculus (i. 50) says, that the Egyptians add five days and a quarter to the 360 days of their 12 months, which statement is generally supposed to refer to a more correct year which had been introduced among the people, while their religious festivals continued to be regulated by the old year. The propriety of this mode of reconciling the two authorities is made probable by the known existence of the Sothiac period (also called the Canicular year, Annus Magnus, &c., derived from Sothis, a name for the star Sirius) mentioned by Geminus, and also by Censorinus and Clement of Alexandria, from older writers. It is obvious that 1461 years of 365 days each make 1460 years of 365¼ days. This period of 1460 Julian years was the Sothiac period. It is impossible to fix any time at which this period was introduced, or to say whether, during its existence as a recognised cycle, it had time to run its whole career. Had it been a real cycle of experiment, it must be imagined that it would have been found to be wrong, to the extent of requiring an addition to the oath; for 1508 real years is nearer to the time in which a year of 365 days would have its beginning in all the seasons successively, and recommence the same process. It is obvious that such a cycle of recurrence was the intention of the Egyptians in constructing the period: their vague year (*annus vagus*) of 365 days, combined with their nearly fixed festivals, depending upon the heliacal rising of Sirius, made the latter take all consecutive positions among the months of the former, gradually falling later and later. Again, if the Egyptians had really gone through a whole recorded period, it is difficult to see how they would avoid discovering that another cycle would be necessary. In the time of their ancient kings the heliacal rising of Sirius would have advanced, by the precession of the equinoxes, about 12 days in one Sothiac period. The beginning of the vague year (365 days) was continually falling back; so that if at the beginning of a period they had noted the day of their vague year on which the equinox fell, and also the day on which Sirius rose heliacally, they would have found that the latter came again to the same day of the vague year fifty years, or thereabouts, before the equinox was similarly restored. This, so far as the star was concerned, would fit their erroneous period very well (1460 instead of 1508); but it is difficult to suppose that astronomers who had discovered the odd quarter of a day which the year requires, should not know within 12 days the time of the equinox.

The epoch of commencement of a Sothiac period is not well determined and only from comparatively modern writers. Censorinus asserts that the consulship of Ulpius and Pontianus (usually placed in A.D. 238) was in the hundredth year of such a period: accordingly B.C. 1322 was the beginning of the preceding period. Clement of Alexandria says that the period began 345 years after the migration of the Israelites from Egypt, a date which differs considerably from that of Censorinus, according to modern chronologers. The point is however of no importance, as no dates were ever recorded in written history by means of Sothiac periods.

SOTIES, or SOTTISES. [Drama; *French Drama.*]

SOULS, CURE OF. [Benefice.]

SOUND. For the various divisions of this great subject we must refer to Acoustics; Echo; Vibrations; Pipe; Scale; &c.; also to the various articles on Music and its theory.

SOUND BOARDS. The boards which are used in floors for the purpose of intercepting the passage of sound between the various storeys of a building, are known amongst builders by the name of *sound boards*. They are introduced in double floors (that is to say, in floors formed by separate systems of joists for the ceiling and for the floor-boards), immediately upon the ceiling-joists; and in single floors they are executed in short lengths, laid upon fillets, nailed on the sides of the deep joists. Upon these boards light plaster, or lime rubbish, or other material able to arrest the passage of the sound waves is laid, and the ordinary floor-boards are then nailed over the whole. Sometimes a mixture of lime and hair is laid upon sound boards as the "pugging material," to use the workman's phrase; and in others, plaster of Paris is used; but it must be observed, in either of these cases, that if the ceiling and the floor-boards should be closed before the moisture of the lime and hair, or of the plaster, has been allowed to evaporate, there is great danger of its producing dry-rot in the timbers. Indeed, whenever sound boarding is used, great precautions must be taken to ensure that no sappy wood be employed; and that the work should be allowed sufficient time to dry. In framed floors it is more easy to secure these conditions than it is in single ones, or at any rate it is more easy to establish a ventilation above and below sound boarding laid upon the top of the lower range of joists, as in the former case, than it is in the case of the boards laid between the single joists.

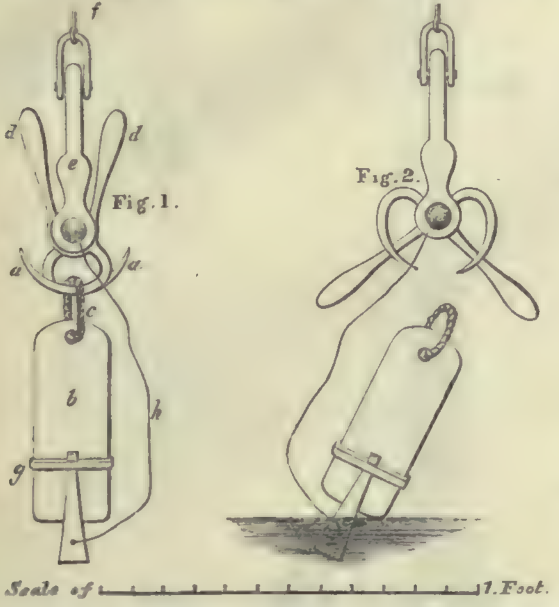
SOUNDINGS, DEEP SEA. Under the word Lead-line a general description has been given of the process of sounding in anchorages and moderate depths upon the coast. Deep-sea sounding requires totally different apparatus. Prior to about 1850, the question of deep-sea sounding was purely geographical and physical. To know the extreme depths of the ocean was but the natural march of that progress which had measured arcs of the meridian, and obtained the altitudes of the highest mountains on the face of the globe; and to descend to the mysteries of the earth's submerged surface, was but the obvious consequence of that insatiable desire for investigation which seems to characterise the minds of men of this particular epoch. But it is no longer a purely scientific question, since it has become a matter of urgent necessity to find, at the bottom of the ocean, a rest for the telegraph-wire.

With the exception of a few spirited researches, chiefly of a private character, little in the way of systematic soundings had been accomplished; though we must not overlook the advantages which deep-sea sounding received from the investigations ordered by Congress in 1849. The conduct of further and more elaborate experiments was confided to Lieutenant Maury, U.S.N., who was empowered by the Congress of the United States of America to equip a small schooner of 100 tons called the Fancy, for various scientific purposes; among them it was specially required that her commander, Lieutenant J. C. Walsh, U.S.N., should attempt to reach the bottom of the sea once in every 200 miles in crossing the Atlantic. Up to this time no particular apparatus for taking deep soundings had been in use: the ordinary round shot slung with strips of canvas was the usual means employed. It was found extremely difficult to determine in some cases the period at which the shot reached the bottom; the weight of some thousands of fathoms of line, and the influences of current and drifting of the vessel, rendered the exact depth attained only appreciable by long experience. The Fancy was, moreover, found too small a vessel for the purpose; the result, however, of the cruise reflects great credit on the commander, since he established the fact, that in some places the depth of ocean was more than 5700 fathoms, or was above six English miles! thus exceeding the height of the most lofty known mountain. This was the greatest depth that had been measured, without finding the bottom, and was attained on the 15th November, 1849, latitude 31° 59′ N., and longitude 58° 43′ W. The time used in the descent of the line to this enormous depth was only 1½ hour, but the line at last broke at the reel, losing the whole 5700 fathoms. We are assured by Lieutenant Maury, that the descent of the sounding line was accomplished without any jerks or checks, beyond those of the friction bands to give uniformity to the descent, so that the weight could not have touched the bottom, and was a fair straight up and down experiment. In this memorable sounding, the lead had a Stellwagen cone fitted to it, and a small apparatus weighing 6 lbs., for ascertaining the depth reached. The line was of steel wire of the best English manufacture. In May, 1850, the United States again determined on exploring the deep sea. Considerable attention was paid to every requisite, and the Albany, Captain Platt, was next equipped for this service; the principal locality of her observations was to be the Caribbean Sea. Instead of steel wire, this ship was fitted with about 40,000 fathoms of twine, weighing about 150 fathoms to the pound. This was usually attached to a 32 lb. shot, which was allowed in its descent to take the turn from the reel without control. After various failures, and the loss of much line and several shot, a useful list of soundings was obtained;—and which are described in Lieutenant Maury's work. The principal result of these experiments was the proving that in no part of the Gulf of Mexico is the depth greater than 1000 fathoms. It became evident, however, that with a *fixed* weight, it is extremely difficult to determine the exact depth when the bight of the line is swept off by an under-current, which, even when the shot rests upon the ground, continues to take the line from the reel with scarcely diminished velocity. This would have a general tendency to give exaggerated depths.

In May, 1851, another United States ship, the John Adams, renewed the soundings of the Atlantic, and accomplished the greatest deep-sea sounding which had as yet been obtained. The bottom was found in latitude 32° 6′ N., and longitude 44° 47′ W., at 5500 fathoms (Lieutenant Walsh, in the Fancy, had reached 5700 fathoms, but found no bottom). In this great sounding two 32 lb. shot were used, which, together with the 5500 fathoms of line, were lost on attempting to recover them:—correcting for drift, the actual depth is estimated by Captain Barron, her commander, at 4825 fathoms, or about 5½ English miles.

It is unnecessary to follow up these observations in detail. The experience gained in them led to various contrivances whereby the saving of the line at the expense of the shot might be effected. In the Dolphin, U.S.N., an improvement was made in having shot so cast as to slide upon an iron rod. Upon the latter touching the bottom, the shot released itself, and the line and rod were more easily recovered.

A great advantage over the rod and shot was gained by the invention of a kind of double claw, acting somewhat upon the principle of that used for detaching the monkey of a pile-driving machine. It was invented by a blacksmith of H.M.S. Spitfire in 1851, named Carmelo Bonnici, a Maltese. Captain Spratt, R.N., who commanded the Spitfire, introduced it to public notice in the 'Nautical Magazine' for 1856.



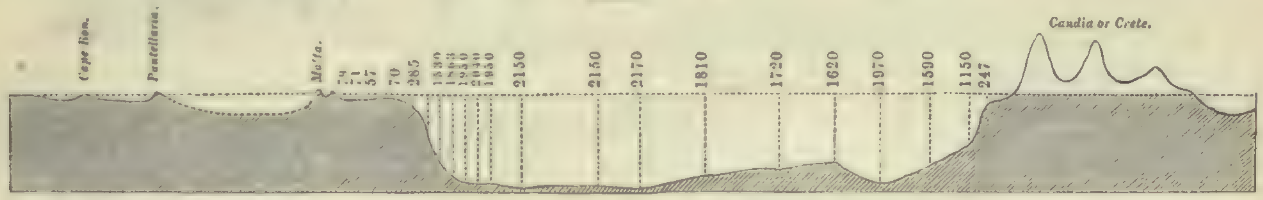
As the increasing demand for submarine telegraphs will much extend the work of deep-sea sounding, we give a few diagrams of the means employed in that interesting operation, as well as some sections of the sea bed, carefully drawn to a scale, and, in order to facilitate comparisons, each of them has the horizontal scale in proportion to the vertical as 30 to 1.

Bonnici's claw, as it is called, consists of two metal hooks of peculiar shape working on a pin, so that on any weight being attached it clasps and sustains a wire or line; its great advantage being that any kind of sinker may be used with it, namely, either a shot or a pig of iron, or, on the want of these, a piece of heavy stone. In the above figures, No. 1 shows the outline of the apparatus when in course of descent, *a a* being the claws hooked into a rope-grummet, *c*, suspending a weight, *b*; the arms, *d d*, of the claws lie close to the link *e*, to which is fastened the sounding-line *f*, and the whole outline is such as to favour the descent of the apparatus; but the moment the lower portion touches the bottom, the arms *d d* being relieved of the weight of the sinker, drop, as in *fig.* 2, and the claws detach themselves from the grummet, and the weight is left at the bottom.

It will be noticed that a piece projects beyond the underpart of the sinker which, among various contrivances, is loosely tied with string, *g*, to the body of the sinker: this has a hollow armed with tallow in the end, to bring up indications of the nature of the bottom bed, as in the ordinary hand-lead. On the sinker being detached from the apparatus, a small string, *h*, attached to the link of the instrument draws this clear of the mass of the sinker, and it is hauled up with the line.

This was a great step towards a better system, but it required considerable care in *setting* the instrument, so as to insure the ready detachment of the weight on reaching the sea-bottom. Captain Spratt, however, made excellent use of it. He was engaged in sounding upon an extensive scale in the Mediterranean. In the accompanying section it will be seen that his greatest depth was 2170 fathoms, or nearly 2½ miles: this was obtained in about lat. 35° 30′ N., and long. 18° 45′ E. It shows that eastward of Malta there exists a small plateau, having on it from 70 to 80 fathoms water, but that 50 or 60 miles from Malta, in the same direction, there is an enormous submarine escarpment of some 2000 fathoms, or 2¼ English miles.

Section 1.

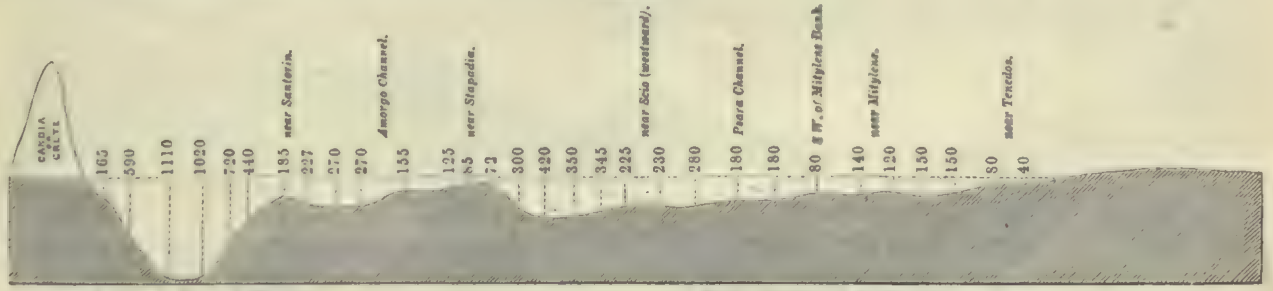


Tunis to Candia or Crete.

Scale—Horizontal 136,000 fathoms } to one inch, or 30 to 1.
Vertical 4,533 „

In the following section we see that the bed of the Mediterranean rises as we proceed northward in the Archipelago, the deepest water (after passing the deeps about Candia) being 420 fathoms, and then gradually shallowing.

Section 2.



Candia, or Crete, to Tenedos.

Scale—Horizontal 60,000 fathoms } to one inch, or 30 to 1.
Vertical 2,000 „

In 1857, Captain T. Mansell, in H.M.S. Tartarus, was occupied in sounding between Alexandria, Rhodes, and Smyrna. He also used Bonnici's claw, but had in addition Lieutenant Brooke's (U.S.N.) apparatus in which had been substituted a conical mass of iron, sliding on a rod. This is an exceedingly simple and ingenious plan, but has been surpassed by improvements yet to be described. Captain Mansell seems to have given each of these instruments a fair trial in the Mediterranean, and records his decided preference for the Bonnici claw. The following will explain Brooke's apparatus. It is remarkable as the one used in discovering the plateau existing between Ireland and Newfoundland.

In *fig.* 3 (col. 683), *a a* are arms working loosely upon a pin at *b*, connecting them with the rod *c*. The sounding line is attached at *d* to the bridle connecting the upper ends of the two arms. The conical weight sliding upon the bar, is held in its position during the operation of sounding by a looped line passing under the base of the cone, and loosely hung on the spurs, *e e*, of the arms; immediately on the sounding-line being relieved of the weight of the apparatus by the latter touching the ground, the arms drop into the position shown by dotted lines, and the loops slip off the spurs, thus detaching the cone altogether, which slips off the bar. But here is supposed to be a defect in the apparatus, inasmuch as the force necessary to draw the rod from the aperture of the cone, when in a much inclined position upon rocky bottom, is found enough to break the line at great depths.

Another excellent form of simple apparatus was invented by Mr. Skead, R.N., Master of H.M.S. Tartarus, and found by Captain Spratt to answer admirably in comparatively shallow water. *Fig.* 4, is a sketch of it. The sounding-line is attached to a small metal

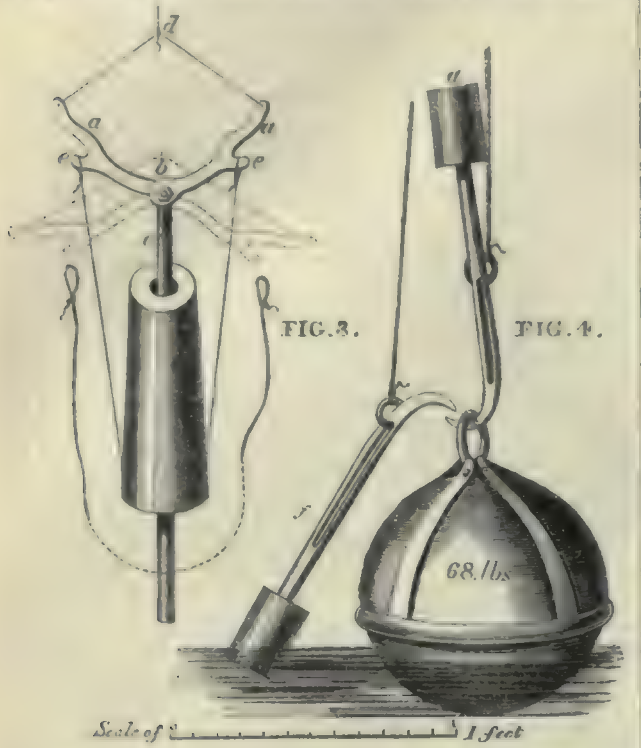


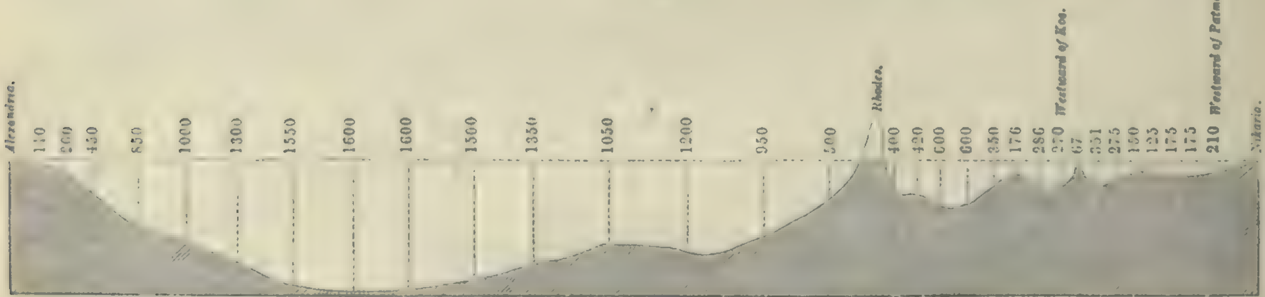
FIG. 3.

FIG. 4.

ring, which slides in a groove in a bar of quarter-inch iron, and 12 inches in length, having a small hook at one end, and a weight at the other, **hollowed and jagged so as to bring up any portion of the bottom. This can be used with either shot or pig-iron, and on reaching the ground the weight *a* descends and unhooks the sinker, which being left at the bottom the simple apparatus is easily recovered without much strain on the sounding-line. The position of the hook at the moment of detachment from the weight is shown at *f*.**

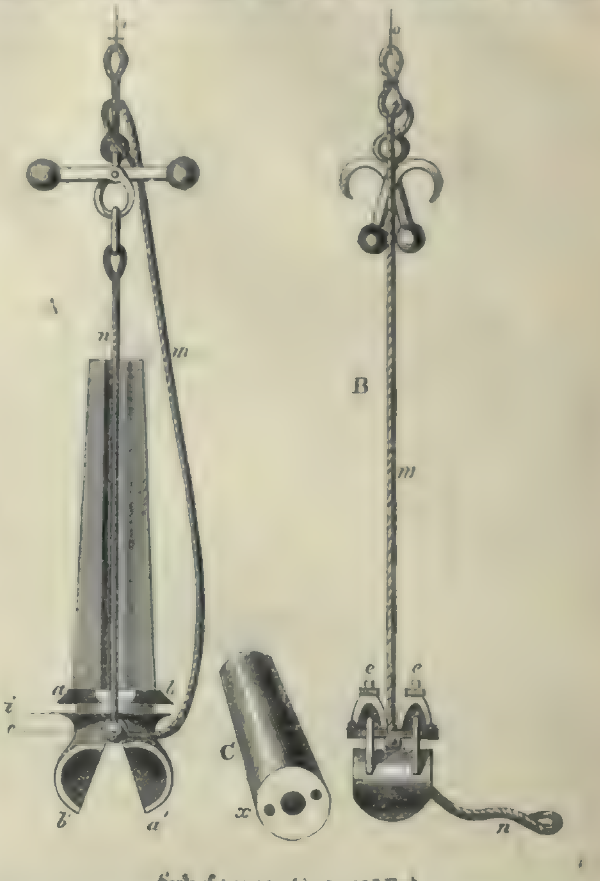
The result of Captain Mansell's labours can be best explained by the following section (3).

Section 3.



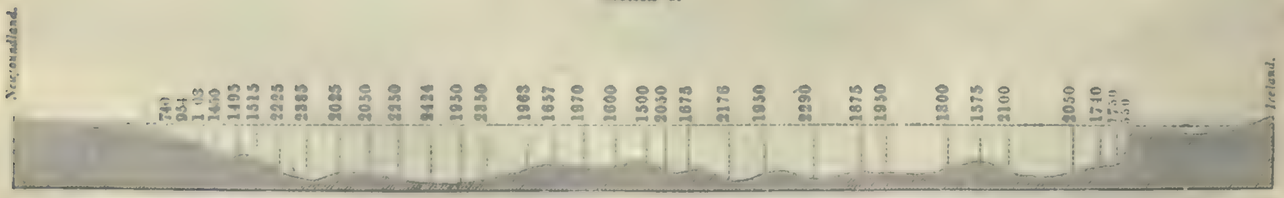
Alexandria to Nikaria.

Scale—Horizontal 71,000 fathoms } to one inch, or 30 to 1.
Vertical 2,367 „



In 1857, Lieutenant (now Commander) Dayman, R.N., was ordered to check the deep soundings which had been taken by the Arctic between Europe and North America, preparatory to the laying of the Atlantic electric cable. [TELEGRAPH, SUBMARINE]. The following (4) is a section published by him, and shows in a remarkably satisfactory manner that the examination of the bed of the ocean at any part of the globe is probably within the power of man even with existing apparatus. In no part of the Atlantic under his observation did he find the depth beyond 2424 fathoms, or about 2¾ miles.

Section 4.



Newfoundland to Ireland.

Scale—Horizontal 254,160 fathoms } to one inch, or 30 to 1.
Vertical 8,472 „

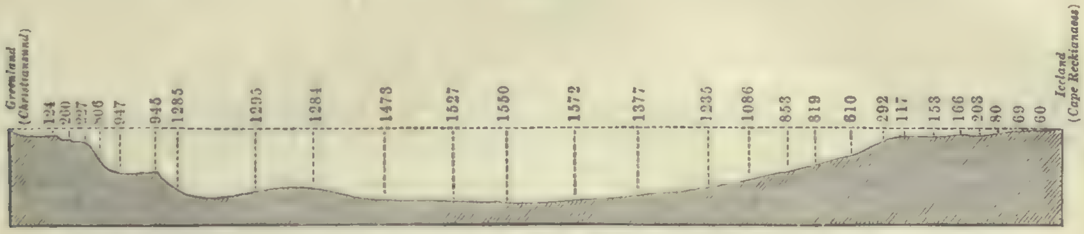
It is unnecessary to mention more than the leading facts connected with deep sea soundings. It becomes, however, an act of justice to remark that the United States' Government, who took the lead in sounding the Atlantic, are doing the same in the Pacific. The United States' schooner Fennimore Cooper was commissioned by Lieutenant Brooke (the experienced officer who invented the sounding apparatus bearing his name) for the purpose.

The only other deep sea soundings which we shall mention are those by Captain Sir F. L. McClintock, of H.M.S. Bulldog, in the Northern Ocean in 1860. It has been shown that much of the success of previous experimenters had depended on the instruments in use. One great object also had been to collect as much of the sea bed at each operation of sounding as possible. Up to 1860 very many contrivances had been in use to effect this, with various results. Captain McClintock had been provided with a modified form of Brooke's machine, but it did not answer his expectations. Much attention was given to improvements by Mr. Roughton, his chief engineer, and Mr. Steil, his assistant; also by Dr. Wallich, naturalist to the ship; but Mr. Steil succeeded admirably in contriving a double-scoop machine wherewith to bring up a considerable quantity of the sea bed. It will be henceforward known as the "Bulldog sounding machine," and is of the form shown in col. 684.

In this, Lieutenant Brooke's plan of a hollow sinker is combined with Bonnici's claws, but the section of its scoop requires some little explanation. The two parts *a a′* and *b b′* move like shears on the pin, *c*, in *fig.* A. Another view of them is in *fig.* B, in which *e e* are two studs, which fit the two holes loosely in the cone, as in C at *x*. When the cone is descending it rests on these two studs and collars, being steadied by the line in A and B marked *n*. A strong india-rubber band, *i*, is attached, so that on the apparatus reaching the ground, the sounding-line, *o*, being relieved from the weight, allows the claws to fall open, as in B, and the part of the line *n*, being released, the cone tilts off the studs, *e e*, and falls, remaining on the ground; the part of the line *n*, unreeving through it, as *n* in B, and the claws and scoop being secured to the part *m*, are hauled to the surface; the removal of the cone from *e e* allowing the india-rubber bands to compress and close the scoops while in the ground, inclosing about 4 lbs. of the bottom of the sea.

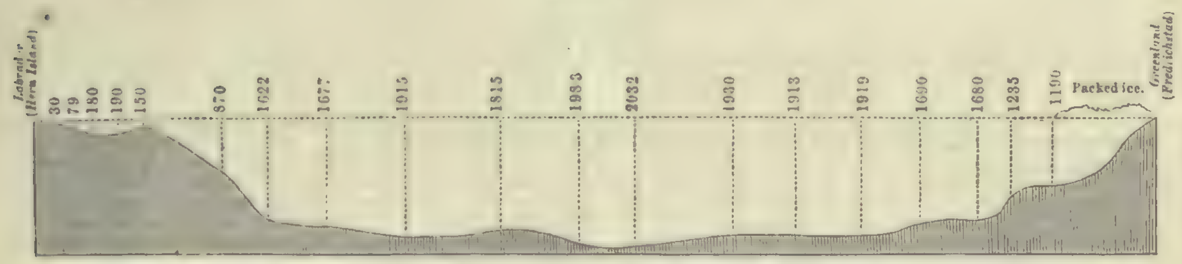
Captain McClintock's results will be best understood by the following sections of his principal soundings.

Section 5.



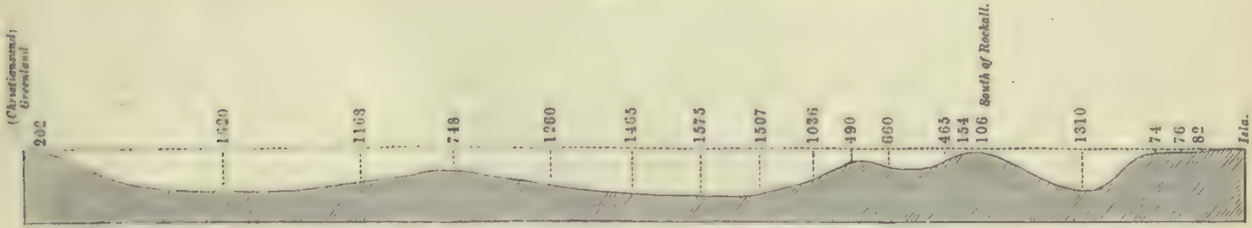
Greenland to Iceland. Scale—Horizontal 120,000 fathoms / Vertical 4,000 ,, } to one inch, or 30 to 1.

Section 6.



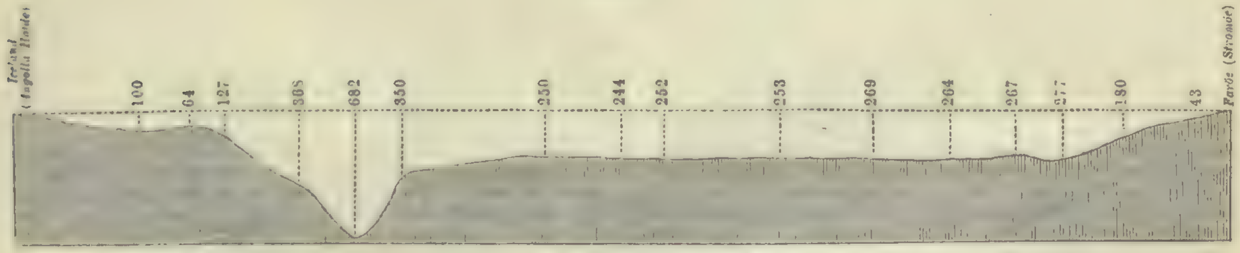
Labrador to Greenland. Scale—Horizontal 90,000 fathoms / Vertical 3,000 ,, } to one inch, or 30 to 1.

Section 7.



Greenland to Isla. Scale—Horizontal 180,000 fathoms / Vertical 6,000 ,, } to one inch, or 30 to 1.

Section 8.



Iceland to Faröe. Scale—Horizontal 30,000 fathoms / Vertical 1,000 ,, } to one inch, or 30 to 1.

All the above sectional diagrams are upon the same relative scale, namely, 30 to 1, and each is referred to the inch. Much valuable information on deep sea sounding may be obtained from Maury's works on the Physical Geography of the Sea: and many very useful details are recorded in the pages of the 'Nautical Magazine.' [SEA.]

SOUNDS, HARMONIC. [HARMONICS; TEMPERAMENT; ACOUSTICS.]

SOUTH KENSINGTON MUSEUM. The formation of a national Museum of Ornamental Art was commenced on a very small scale in 1838. Originally intended merely as an adjunct to the Central School of Design, its progress was comparatively slow. By the Great Exhibition of 1851, however, not only was attention directed strongly to the necessity of forming a more comprehensive museum for the especial use of manufacturers and art workmen, and which should at the same time serve to interest and instruct the public generally; but it was also seen that the exhibition afforded a singularly favourable opportunity for securing the nucleus of such a museum. A selection of objects was accordingly made from the Indian, Continental, and British sections, and along with the articles previously purchased for the Museum of the Schools of Design, exhibited to the public in a suite of rooms appropriated to the purpose in Marlborough House. The Museum of Ornamental Art thus formed, was in the following years considerably increased by the purchase of the collection of porcelain and pottery of Mr. Bandinell, and by extensive purchases made at the Bernal sale. In 1857 the museum, which had been placed under the Department of Science and Art [Science and Art, Department of], was removed to the iron building erected by the Commissioners of the Exhibition of 1851, on the ground purchased by them at South Kensington. The Museum of Ornamental Art has since been very largely increased, and other collections have been added to it, and the whole has been incorporated into what is officially designated the South Kensington Museum of Science and Art; buildings of a permanent character having been at different times added to the original iron structure to meet the growing requirements of the case.

As at present constituted, the South Kensington Museum consists of three distinct divisions; those, namely, of Ornamental Art; of Fine Art; and of Science. In the Companion to the Almanac for 1861 is given a full analysis of the Museum, to which we refer for further details, contenting ourselves with giving here a brief statement of its general character.

The *Museum of Ornamental Art*, as it formed the foundation, may still be regarded as the distinctive feature, of the South Kensington Museum. Although intended primarily to aid the Schools of Design, and to improve the manufactures of the country, it has of late years, in a great measure, to use the words of its director, "settled itself into Mediæval Art," or rather the art of the mediæval and renaissance periods. Within these limits it is, however, very comprehensive in its range, and articles have been sought out for purchase with great industry and judgment. The Museum of Ornamental Art is arranged in eighteen classes:—(1) Sculpture, in which are many exquisite specimens of Italian architectural sculpture of the renaissance period, carvings in wood, ivory, bone, &c., including some admirable works by Fiammingo, with some important examples of artists of an earlier period; bronzes and terra-cottas and models, among which are some by Michel Angelo. (2) Glyptic and Numismatic Art, including gems, medals, and seals. (3) Mosaics, Marquetry, &c. (4) Painting, almost exclusively of a decorative character. (5) Japanned or Lacquered Work. (6) Glass Painting—comprising Italian, German, and Flemish examples from the 13th century to the decline of the art, with a few of recent execution. (7) Enamels on Metal, an extremely choice and valuable collection, especially rich in early German champlevé works, and the much-prized Limoges enamels, and including also some interesting specimens of modern Indian and Chinese work. (8) Pottery, as a whole, one of the finest collections in Europe, including a few examples of Egyptian, Greek, Etruscan, and other antique ware; Hispano-Moresco ware; early Italian enamelled and incised ware; an almost matchless collection of Gubbio and other lustred wares, and Majolica of the various Italian manufactories; modern reproductions; Persian painted ware; Morocco enamelled earthenware; Palissy, Nevers, and other French glazed and enamelled earthenware; Delft, old German, Dutch, and Flemish stoneware; old Saxon red stoneware; Hindoo and other Oriental earthenware; Oriental porcelain (China and Japan); Dresden and other German porcelain; old Sèvres; modern Sèvres; French porcelain of various manufactories; Italian, Dutch, Spanish, and Portuguese, Swiss, Danish, and Russian 18th century porcelain; old English earthenware, stoneware, and porcelain, &c., of all the principal varieties (including a fine collection of old Wedgwood), and English and Foreign modern porcelain, earthenware, biscuit, Parian, &c. (9) Glass Manufactures, including a very choice selection of old Venetian, German, and French glass, and a few examples of modern glass, chiefly French and English. (10) Works in Metal, comprising wrought-iron coffers, &c.; locksmith's work; instruments; knives, forks, spoons, &c.; firedogs and stoves; candlesticks, chandeliers, &c.; antique Greek and Roman ornamental bronzes; Oriental bronze vessels; metal household utensils; mediæval ecclesiastical utensils; modern bronze vessels; goldsmiths' work both ancient and modern; damascene work; nielli. (11) Watch and Clock Work. (12) Jewellery and personal ornaments in the precious metals, ancient, mediæval, modern, and Oriental. (13) Arms, Armour, and Accoutrements. (14) Furniture, Upholstery, &c., including a singularly interesting variety of old Italian cassone or marriage chests, carved cabinets, mirrors, &c. (15) Leather Work. (16) Basket Work. (17) Textile Fabrics,—as might be anticipated in a British Museum of Ornamental Art, the most extensive collection of the kind extant. (18) Bookbinding and Book Decoration generally.

The Fine Arts Division comprises the Sheepshanks' collection of 234 modern oil paintings; a small collection of drawings and sketches also presented to the nation by Mr. Sheepshanks; and a collection of 50 water-colour paintings, the gift of Mrs. Ellison of Sudbrooke, to which other drawings have been added by purchase: these collections are more particularly noticed under National Gallery.

The *Science Division* consists of—1. An Educational Collection, in which are brought together, models of schools, school-fittings, school-books (and a reading-room, in which to examine them) maps and diagrams, philosophical instruments, &c., in fact, as far as practicable, whatever may serve to guide or assist those engaged in teaching. 2. Collection of Animal Products. 3. Food Collections— in which are shown the chemical compositions of the various substances used as food. 4. Structural Museum, in which are collected the materials employed in building, &c.

These form the Museum proper; but to them are to be added other collections which are placed in the same building, though they do not belong to the Department of Science and Art. They consist of the British pictures belonging to the National Gallery, which are placed here temporarily [National Gallery]: collections of architectural casts belonging to the Architectural Museum Association and the Royal Academy; a small collection of modern sculpture, chiefly casts, and the Patent Museum belonging to the Commissioners of Patents. Certain rooms are also set apart for the reception for a limited time of choice collections of articles of ornamental art belonging to private individuals; and there are now usually five or six of these "Loan Collections" on view here at one time, containing commonly many specimens of great interest and value.

The total cost of the South Kensington Museum up to July 1860, was 167,000*l.*, including everything except management, the annual expenditure on which is about 7000*l.* Of the above sum the land cost 60,000*l.*, the buildings 54,536*l.*, the collections 58,269*l.* The value of the private gifts to the Museum, including the Sheepshanks and Ellison collections of paintings, is estimated by the director at upwards of 88,000*l.* The permanent buildings which have been erected are intended to form part of a spacious structure which is to cover an area of above ten acres, and to supply all the requirements of the Department at South Kensington. [Science and Art, Department of.] In its main features the building is intended to consist of a centre and two great projecting wings, the fronts of which are to be connected by an open corridor. In the centre will be the Lecture Theatre, Art Training Schools, &c. The eastern wing will be appropriated to the Art-collections; the western to the Educational collections, Art-Library, offices, residences, &c. The extreme length (facing Cromwell Road) will exceed 700 feet; the extreme depth (or western façade) 650 feet, but the site is very irregular. The design is by Captain Fowke, the official architect and engineer to the Museum; the total cost is estimated at 214,000*l.*, but at present only the eastern wing is in course of erection.

All the collections are open free to the public on Mondays, Tuesdays, and Saturdays in each week; on the other days (being "students' days") the public are admitted on payment of 6*d.* each person. The collections are also opened to the public free on the first two evenings of the week—an innovation which has proved exceedingly popular. To the Art Library—a very excellent one—though formed primarily for the students, any person is admitted on payment of a trifling fee.

SOVEREIGN. [Money.]

SOVEREIGNTY. *Supranus* is a low Latin word, formed from *supra*, like *subtranus*, another low Latin word, formed from *subtra*. (Ducange *in vv.*) These words, however, though they do not belong to classical Latinity, are formed according to the same analogy as the classical word *supernus* from *super*. From *supranus* have been derived the Italian *soprano* or *sovrano*, and the French *souverain*, from the latter of which has been borrowed the English word *sovereign*. In the old English writers the word is correctly spelt *soverain* or *soverein* (Richardson *in v.*); the received orthography seems to be founded on the erroneous supposition that the last syllable of the word is connected with *reign*, *regnum*. Milton spells the word *sovran*, deriving it from the Italian; but it passed into our language from the French.

Having explained the etymology of the word *sovereign*, with its derivative, *sovereignty*, we proceed to consider the meaning of the term sovereignty as it is understood by political and juridical writers.

In every society not being in a state of nature or a state of anarchy [Anarchy; Social Contract], some person or persons must possess the supreme or *sovereign* power.

The marks by which the possession of the sovereign power may be distinguished are mainly two, the one positive and the other negative; namely:—

1. A habit of obedience to some determinate person or persons, by the community which he or they assume to govern.

2. The absence of a habit of obedience, on the part of the same person or persons, to any person or government.

Whenever these two marks meet in any person or body of persons, such person or body possesses the sovereign power; on the other hand, if either of the two marks be wanting, the person or body is not sovereign. For example, the local government of Jamaica or Canada, being in the habit of obeying the English parliament, is not a sovereign or supreme government; whereas the governments of the smaller German states, although they may occasionally defer to the wishes of Austria or Prussia, are not in a habit of obedience to these or any other states, and therefore are sovereign governments. Again, a body of persons calling themselves a government, but unable, through their weakness, to secure the habitual obedience of the people, are not sovereign, and would not be recognised as a sovereign government by foreign states.

Inasmuch as it is impossible to fix the precise moment at which a habit of obedience to a foreign government ceases, it is difficult for foreign states to determine when they will recognise the sovereignty of a territory, once dependent, which has achieved its independence.

The sovereign powers include all the powers which can be exercised by a government. They include the legislative power, the executive power, the power of making *privilegia* [LAW; LEGISLATION], the power of declaring peace and war, and of concluding treaties with foreign states, the power of making contracts with private individuals, and the power of instituting inquiries.

Sovereign power abstractedly is unlimited by any legal check or control. The securities for its beneficial exercise are derived exclusively from the balance of interests and the influence of public opinion.

Sovereign or supreme governments are divided into MONARCHIES and REPUBLICS; and REPUBLICS are divided into ARISTOCRACIES and DEMOCRACIES.

It is commonly, but erroneously, thought that the sovereignty resides in every person who bears the name of *king;* in other words, that every king is a monarch. Accordingly those kingdoms in which the king is not strictly a monarch are called "limited monarchies;" and the king is supposed to be a sovereign whose power is checked or controlled by certain popular bodies; whereas, in truth, the sovereignty is divided between the king and the popular body, and the former does not possess the entire sovereignty. This subject is further explained in KING, MONARCHY, and ROYALTY.

The subject of sovereignty is well explained in Mr. Austin's 'Province of Jurisprudence determined.' The received doctrines upon the subject will likewise be found in the treatises on international law. The 'Leviathan' of Hobbes contains a view of the nature of sovereignty, which has been often misunderstood and misrepresented by later writers.

SOWING AND SOWING-MACHINES. The sowing of the seed has always been looked upon as one of the most important operations of husbandry. Much of the success of the future crops depends on the time and the mode in which the seed is committed to the earth. After the land has been well prepared by judicious tillage and manuring, many accidents and circumstances may disappoint the hope of the farmer, and the crop may be scanty or fail altogether. The weather and the seasons are not under his control, and he must submit to the dispensations of Providence with pious resignation; but much also depends on his own judgment and skill. If he selects the best seeds, chooses the proper season for sowing them, and has them carefully distributed and properly covered with earth, as their nature requires for the most perfect germination, and thus also protects them from the voracity of birds or insects, he will have a much greater prospect of success, under all circumstances, than if he were careless or negligent.

The most common mode of sowing the seed is by scattering it as evenly as possible over the ploughed surface, as it lies in ridges from the plough. The harrows follow, and crumbling down the ridges, cover the seed which has fallen in the hollows between them. It requires an experienced sower to scatter the exact quantity over a given surface, without crowding the seed in one spot, and allowing too great intervals in another. Hence the farmer who does not himself sow the seed, invariably chooses the most experienced and skilful labourer to perform this work. Notwithstanding every care and attention on the part of the farmer or master, the labourer will often relax and become careless, and the result appears only when it is too late to remedy it. This has given rise to the various attempts which have been made to invent machines for sowing the seed, such as should insure perfect regularity. Of some of these we will now give a short account.

One of the simplest of these machines consisted in a hollow cylinder, with one or more rows of holes in a line parallel to the axis. These holes can be stopped in part if required. The seed is put into the cylinder, the length of which is equal to the width of the land, or stitch, which it is desired to sow at a time. By shaking this when held horizontally and at right angles to the path of the sower, the seed is scattered with considerable regularity: one inconvenience of this instrument is that it requires to be filled frequently, and that much still depends on the attention of the operator. Accordingly it was very soon laid by. The idea, however, was followed up and improved upon in the *sowing-barrow,* an instrument still extensively used for sowing grass-seeds. It consists of a wooden trough placed on the frame of a light wheelbarrow. An iron spindle, furnished with circular brushes at regular intervals, runs the whole length of the trough, and is turned by means of simple machinery connected with the wheel. Opposite each brush is a brass plate, with holes of different sizes, which can be partly closed by means of a circular slide. According to the size of the seed to be sown and the quantity to be scattered, the holes are opened or shut. The seed is put into the trough, which has a cover or lid; and by merely wheeling the barrow in a straight line, a breadth is sown equal to the length of the trough, usually 12 or 15 feet. But this machine cannot conveniently be used in windy weather, which disperses the seeds irregularly; and it is very little superior to sowing by the hand, except in the case of small seeds, which cannot so well be spread evenly by the hand.

The drill husbandry has suggested other more complicated machines, of which some account will be found in the article DRILL. The principle of these is to deliver the seed by means of funnels, each corresponding to a small furrow made by a coulter placed immediately before the funnel; and some of these machines perform the work very regularly and satisfactorily. As the inequalities of the ground require that the coulters should move up or down, to allow for these inequalities, the seed cannot be accurately deposited at a given depth; and some further improvement in the mode of drilling is yet desirable, though much has been effected. The patent lever-drill in common use is very imperfect in its work, and the remedy lies in the greater attention to the preparation of the surface. When this is effected, the levers may be set aside, and a much simpler drill, such as was used at first, may replace it. The object is to make furrows of equal depth in which to deposit the seed, and to cover this uniformly. The land must consequently be more carefully prepared by repeated harrowing and rolling, till the surface resembles the seed-beds in a garden. A simple drill, which makes equidistant furrows at a given depth, in which the seed drops regularly, will then do better work than a more complicated machine; but if still greater accuracy and perfection are desired, the dibble must be had recourse to. No one will deny that seed deposited by means of a dibble is distributed more equally and covered with a more equal depth of soil than by any other means, and that there is a great economy of seed in this mode of sowing; but the slowness of the operation, and the number of hands it would require to dibble all the seed on a large farm, have prevented its being very generally adopted. [ARABLE LAND.] Many attempts have been made to invent machines to imitate the work done by hand in dibbling, but hitherto with no marked success, owing chiefly to the difficulty of clearing the dibbles from the adhering soil, and making a clean hole, and also of letting the seed fall exactly in the dibble-holes.

SOY, is obtained from the *Soja hispida,* or *Soja japonica* [SOJA, in NAT. HIST. DIV.] From the seeds of this leguminous plant, the Japanese prepare the sauce termed *Sooja,* which has been corrupted into *Soy.* The beans are boiled until the water is nearly evaporated, and they begin to burn; when they are taken from the fire, and placed in large wide-mouthed jars, exposed to the sun and air; water and a certain proportion of molasses or very brown sugar are added. These jars are stirred well every day, until the liquor and beans are completely mixed and fermented; the material is then strained, salted, and boiled, and skimmed until clarified. There are two or three qualities of soy. Japanese soy is much esteemed in China on account of the superior manner in which it is made. Soy is only sparingly used as a sauce in this country.

SOYMIDA. [SOYMIDA, in NAT. HIST. DIV.]

SPACE AND TIME (Mathematics). We do not here propose to enter into any discussion of the doctrines of psychologists as to the idea of space, or as to whether it be innate or acquired. Space and time are essential to thought, and are, come by the notions how we may, necessary attendants on our own consciousness of existence. It is possible for imagination to picture the annihilation of all things, itself included, or to fancy that it can form such a picture, which is the same thing; but what then would remain (in the thoughts)? Infinitely extended empty space, lasting through infinitely extended time. Existence of space and successions of existence we may defy the speculator to deprive himself of for one moment. The greatest proof we have of our ignorance of the Creator of all things is the absolute impossibility which we find of making the necessity of his existence as real a conception of our minds as that of space or time. The most religious man will read with pleasure a work on natural theology tending to prove that there must be a God; but who would bear ten pages of a serious attempt to demonstrate the existence of space and time?

In these ideas we have the foundation of the mathematical sciences; for from space follows form, which is the conception of the manner in which one part of space is separated from the rest, and from the investigation of forms arises geometry. Again, time is only apprehended by succession of events or ideas, and succession or repetition gives the notion of *numbering.* And though *collection* is sometimes stated to be the leading idea in *number,* yet it may be asserted that number in the last sense is not the object of arithmetic, except as furnishing the subject of numbering. The leading phrases of arithmetic suggest the idea of time, and are derived from it. How often is 2 contained in 12? Six times. The 2 presented to the thoughts at six different times is the mode in which the collection of 12 is counted by twos.

From both space and time we get the notion of direction, but in very different manners. The extremities of a portion of length give the idea of a point of space, a fundamental notion of an indivisible index of commencement or termination. The extremities of time give the notion of points of time, or indivisible portions of duration. No point of space contains any space; no point of time lasts any time. If we choose a point of space or a point of time, we can in our thoughts set out from the former in an infinite number of different ways; from the latter, in only two. This is the law of thought, upon which it is useless to speculate; but it is followed by important consequences. So long as algebra, the science of reasoning by symbols, was founded only on notions of arithmetic or succession, its ideas were not competent to furnish explanation to all the results of its mechanical processes. As soon as the same rules were transferred to ideas of space, or made to spring from geometrical explanations, the mysteries of that science gradually vanished.

From space and time, also, we get the idea of infinity, a subject which has been already treated [INFINITE]; but only in such a point of view as would meet the objections of those who cannot reason clearly on absolute infinity. That space and time are unbounded, is the simple consequence of their being necessary to our notion of the existence of anything: we speak of our conceptions of them. For if it could be imagined that *space ceased* at a certain boundary, it would be as easy to make it cease in our own neighbourhood; and if duration could be imagined to have an end, it would not be difficult to place ourselves in thought within five minutes of that end. The denial of the possibility of our approaching the boundary of space or time in our thoughts, is the same thing as the denial of the existence of such a boundary; and the notion of infinity becomes a relief from the incongruity of the attempt to conceive existence stripped of its essential conditions. But it might be asked why not, as to space at least, consider real existing extension, not as the object of our thoughts, but as it would exist if we were not alive to think? Is it, or is it not, physically possible to go on for ever in space? If a person could provide himself with an unlimited supply of motive-power, air, heat, food, &c., must we, or must we not, say that there is anything to hinder his travelling to all eternity? For ourselves, we should say there is clearly nothing to hinder; but of course we cannot appeal to experiment, and it may be only the impossibility of destroying our own conception of space which dictates an answer as to that external reality which, let metaphysicians say what they please, can always be established by a wave of the hand. We should have supposed that, mysterious as the connection may be between the external world and our impressions of it, the possibility of really infinite external space would be admitted by any one, unless he held the metaphysical system of Berkeley, which denies the necessity of any external substratum of our conceptions, and substitutes the direct agency of the Creator; and we should have thought it impossible to maintain the necessary finitude of *matter*, without also maintaining the same of real external space. Nevertheless, to show how differently these subjects strike different persons, we quote the following from a dissertation of an eminent writer:—"Every *real, existing, material* body must enjoy that indefeasible attribute of body—namely, *definite place*. Now place is defined by *direction* and *distance* from a fixed point. Every body, therefore, which does exist, exists at a certain definite distance from us, and at no other, either more or less. The distance of every individual body in the universe from us is therefore necessarily admitted to be finite." Now it will hardly be denied that the space which a body fills is as real and existent as the body itself, and this whether so occupied or not. Leave out the word *material* in the above, and for "body" read "part of space," and the argument remains as good as before, ending with a denial of the infinity of space. Every *assignable* body is at a finite distance from us; but this is an identical proposition contained in the meaning of the word assignable. But who is *therefore* to deny the following? Name any distance, however great; matter exists at still greater distances.

If we estimate the reality of a conception by its necessity, which is what we do when we settle the pre-eminence of space and time among our ideas, then it is certain that the conception of infinity is as real as that of space or time, being essentially united with them. Many mathematicians try to deny this, and substitute various modes of speaking to avoid the introduction of the idea. It is true that the notion of infinite is one which it is difficult to use without falling into error; a very good reason for avoiding it until the understanding has been well practised in mathematical deduction, but none for denying its existence. Why say that the notion of infinity arises from our not being able to assign a limit, when we know that we feel something more positive; when we are as certain as we are of any right to use the words *can* and *cannot*, that there *cannot be* a limit, to either space or time? Those who examine the views of different writers on the first principles of science see a great variety of modes of expression on this point, but a uniform practical use of nothing more than the *denial of finitude*, accompanied by the mere expression of *incapacity to attain infinity*; resolutely coupled, in many cases, with a determination not to allow any words capable of expressing the *absolute notion of infinity* which actually is before the thoughts. Now it should be the object of elementary writing, while guarding the avenues to error which branch in all directions from an improper use of the word infinite, to acknowledge the existence of the idea, and to make a gradual preparation for its correct and legitimate use. Both infinitely small and infinitely great ought to become terms which may be employed without fear; and the student who has been trained to the natural and healthy use of all his notions will in the end succeed better than the one who has had some of them tied up from the beginning because they are somewhat difficult or somewhat unsafe to use at first.

So soon as an attempt is made to fetter one branch of thought, the effect is sure to be immediately felt in others. The infinite divisibility of space is a truth of the same sort as its infinite extension. *Matter* may not be divisible without end, and the truths of modern chemistry would seem to show that there are ultimate particles inseparable by chemical, and still less by mechanical, means. But there is a solvent which everyone has it in his power to apply to space; it is the intuitive conviction that every portion of it, however small, except that ultimate notion which is called a point, is divisible into parts, which are themselves divisible into parts; a process which may be continued without end. Now, a person who trifles with the notion of infinite extension, and persuades himself that he has not the idea, will probably end by denying infinite diminution; and as motion, however small it may be, requires the succession of positions answering to an unlimited separation of the time of motion into parts, the next step will be to deny the infinite divisibility of time, and the possibility of motion, as commonly conceived. Change of place will be imagined to be physically impossible, if it be asserted that between the first and last positions there have been an infinite number of others; and the mind will be driven, in order to avoid the notion of infinity, into a sort of opinion that motion is a very large (but finite) number of annihilations and re-creations: annihilation in one spot, and re-creation a little farther on, without anything intermediate. This is no imaginary case; and it seems to us that when this theory of motion is once attained, nature has taken a satirical revenge for the attempt to smother her conceptions.

The errors which arise from the improper use of the notion of infinite, lie mostly in the idea that all that is proved of finite space or time must necessarily be true of the infinite. We pass over the error that all infinites must be equal, as being that of the merest beginner; there are enough remaining to claim great caution. The process adopted in the article INFINITE is perhaps the best way of habituating the young mind to the rigorous attainment of results, provided only that the understanding be duly apprised that such a course of proceeding is not pursued because there is *not* infinity, but because there *is*, and because the notion, though inevitable, is not easily used. The road need not be carried over any unsafe foundation; but that is no reason why the quicksand and the marsh should be left out of the map.

SPACES, in Music, the intervals between the five lines forming the staff. [STAFF.]

SPAHIS (or rather *Sipâhis*, from the Persian *sipah*, meaning a cavalry soldier), are a body of Turkish cavalry organised by Amurath I. (Múrad), who was also the founder of the Janizaries. Their number varied according to circumstances, but amounted sometimes to 20,000. They enjoyed many privileges in common with the Janizaries. Their usual arms were a sabre, a lance, a jereed or dart about two feet long, which they hurled with great dexterity and strength, and a second sabre, or rather broadsword, attached to the saddle. Some of them had also a carabine and one or two pistols. At one time they were the most formidable body of cavalry in the Turkish army; but being an undisciplined and unruly militia, they were, together with the Janizaries, dissolved by sultan Mahmud, and their place is now supplied by the Bashi Bazouks. [JANIZARIES.]

SPANIOLITMIN. [LICHENS, COLOURING MATTERS OF.]

SPARTEIN. [SCOPARIN.]

SPASM (from the Greek σπασμός) is an unhealthy, involuntary, and forcible contraction of muscular tissue. The term is almost synonymous with *convulsion*, but is more generally applied than that word is to the unhealthy painful contractions of the heart, intestines, and other involuntary muscles.

Nosologists have distinguished spasms into clonic, in which the muscular contractions alternate rapidly with relaxations (as in epilepsy), and tonic, in which the contracted fibres remain for a long time rigid, as in tetanus; but in nature the distinction is not well marked. Spasm has also often been regarded as occurring in many tissues in which it is perhaps not possible, such as the small blood-vessels. In the present day its occurrence is believed to be limited to the muscles. What their condition is when affected by spasm is not precisely known. Very generally the contraction is unnatural, not only in its origin and its continuance, but in its extent; for it does not take place simultaneously, or in a regular succession, in each part of the muscle, but, as one may often see in common cramp, it affects a single portion of the muscle, drawing it up into a hard mass, while the fibres above and below it are much less contracted, or are even elongated.

The greater number of spasms seem to depend on an irritation of the nervous centres. Sometimes they are produced by primary disease in those parts, but much more commonly they are the results of irritation propagated from some disordered organ to the brain or spinal cord, and thence reflected through the motor nerves of the muscles in which the spasm occurs. Hence probably the frequency and the aggravation of cramps, and other more important spasmodic affections, when the digestive organs are disordered, the dependence of a variety of spasms or convulsions on the irritation of teething, &c. Much less, however, is known of the nature of spasm in general than of the best methods of treating it, and of the effects which it produces in the several organs which it affects. These are treated of in the articles ANGINA PECTORIS; ANTISPASMODICS; ASTHMA; COLIC; CONVULSIONS; EPILEPSY; HYDROPHOBIA; TETANUS, &c.

SPEAKER. [PARLIAMENT.]

SPEAKING-MACHINE. Various attempts have been made to imitate the human voice by means of a machine. In 1779, the Imperial Academy of St. Petersburg proposed, as one of their prize questions, an inquiry into the nature of the vowel sounds, and the construction of an instrument for imitating them. The prize was awarded to M. Kratzenstein ('Journal de Physique,' xxi), and his principle consisted in the adaptation of a free reed, in all respects similar to that represented under HARMONIUM, to a set of pipes of peculiar forms, determined by repeated trials. About the same time, M. Kempelen, of Vienna, best known for his ingenious fraud, the so-called automaton chess-player, succeeded in producing the vowel sounds by adapting a reed to the bottom of a funnel-shaped cavity, and placing his hand in various positions within the funnel. He also contrived a hollow oval box, divided into two portions, attached by a hinge so as to resemble jaws, and by opening and closing them the sounds which issued from a tube connected with the reed produced A, O, OU, and an imperfect E, but not I. He afterwards succeeded in obtaining, from different jaws, the sound of the consonants P, M, L; and by means of these vowels and consonants he could produce such words as *mamma, papa, aula, lama, mulo.* He afterwards succeeded in imitating the human organs of speech by having only one mouth and one glottis. The mouth consisted of a funnel- or bell-shaped piece of elastic gum, to which was added a nose made of two tin tubes. When both tubes were open, and the mouthpiece closed, a perfect M was produced; and when one was closed and the other open, an N was sounded. He also obtained a tolerable resemblance of the four sounds D, G, K, T, or rather a modified P, and at length succeeded in producing entire words and sentences, such as *Constantinopolis; opera; astronomy; Vous etes mon ami; Je vous aime de tout mon cœur.* We learn from a letter from Mr. Thos. Collinson to Dr. Hutton, who had seen the machine in London, and afterwards at Kempelen's house in Vienna, that the sounds issued, not from a speaking figure, but from a rectangular box about three feet long, placed upon a table and covered with a cloth. Kempelen set it in action by introducing his hands beneath the cloth.

Professor Willis, in the third volume of the 'Transactions of the Cambridge Philosophical Society,' shows that by using a shallower cavity than that employed by Kempelen, he could dispense with the introduction of the hand, and by sliding a flat board over the mouth of the cavity could obtain the whole series of vowels, in the order U, O, A, E, I. The apparatus was, of course, connected with a wind-chest and a double pair of bellows. Mr. Willis also used cylindrical tubes containing a reed, with a contrivance for varying the length of the tubes by means of sliding joints. When the tube was much less than the length of a stop-pipe in unison with the reed it sounded I: and by increasing the length of the tube it gave E, A, O, and U; but what was remarkable, when the tube was lengthened so as to be 1¼ times the length of a stop-pipe in unison with the reed, the vowels began to be sounded in an inverted order,—namely, U, O, A, E,—and then again in a direct order, I, E, A, O, U, when the length of the tube was equal with twice that of a stop-pipe in unison with the reed. When the pitch of the reed was very high, it was impossible to sound some of the vowels, which Mr. Willis remarks is exactly the case with the human voice, female singers being unable to pronounce U and O on the highest notes of their voices.

SPEAKING TRUMPET. The efficiency of this instrument is due to the repeated reflection of the sound from side to side in passing through it, and its ultimate reflection from the mouth of the trumpet, in such a way as either to collect the rays of sound into a focus at a distance, or to project them forward in parallel lines, instead of allowing them to diverge in all directions. *Fig.* 1, illustrates this theory, of which there are many modifications, some of them founded on the supposition of a very close analogy between the motion of sound and that of light. These have given rise to many suggestions respecting the best form and degree of curvature of the sides of the trumpet. Some writers recommend a simple cone, the mouth-piece being at the apex: these explain the motion of the rays of sound on the principle shown in *fig.* 2, in which, as in *fig.* 1, the dotted lines represent the rays.

Fig. 1.

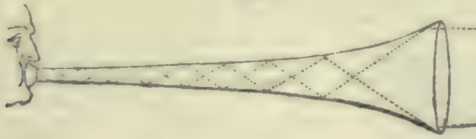
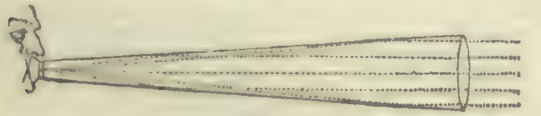


Fig. 2.



In Dr. Young's 'Lectures on Natural Philosophy,' the following remarks occur: "If an ellipsis be prolonged without limit, it will become a parabola; hence a parabola is the proper form of the section of a tube calculated for collecting a sound which proceeds from a great distance into a single point, or for carrying a sound nearly in parallel directions to a very distant place. It appears, therefore, that a parabolic conoid is the best form for a hearing trumpet, and for a speaking trumpet; but for both purposes the parabola ought to be much elongated, and to consist of a portion of the conoid remote from the vertex; for it is requisite in order to avoid confusion, that the sound should enter the ear in directions confined within certain limits: the voice proceeds also from the mouth without any very considerable divergence, so that the parts of the curve behind the focus would in both cases be wholly useless. A trumpet of such a shape does not very materially differ from a part of a cone, and conical instruments are found to answer sufficiently well for practice; it appears, however, unnecessary to suppose, as M. Lambert has done, that they differ essentially in principle from parabolic trumpets. It is not yet perfectly decided whether or no a speaking trumpet has any immediate effect in strengthening the voice independently of the reflection of sound." [Ear Trumpet.]

Speaking Tubes are used in large buildings for conveying messages from one part to another, and sometimes on shipboard from the captain's cabin to the topmast. These tubes are cylindrical, and the rays of sound proceeding from the mouth at one end of the tube instead of diverging in the air are confined within the tube, and successively reflected from its sides, so that a much larger number of rays meet the ear at the farther end than if they had travelled without being reflected. The shafts of mines, wells, and chimneys produce a similar effect.

SPECIAL OCCUPANCY. [Occupancy.]

SPECIALTY, SPECIALTY DEBT, or debt by special contract, is a debt which becomes due or is acknowledged to be due by an instrument under seal. [Deed.]

The nature of a debt by simple contract is explained under Simlpe Contract.

Blackstone considers a debt of record, that is, a debt which appears to be due by the judgment of a court of record, as a "contract of the highest nature, being established by the sentence of a court of judicature." This is, however, an erroneous view of the matter. It is simply a rule of law that a debt for which the judgment of a court of record has been obtained has a priority over other debts.

SPECIES. This word is used in mathematics, or rather has been used, in two different senses. In the first place, by Euclid, who means by figures of the same species those which have the same form, whatever may be their size. Thus, in the Data, when the form of a figure is given, he designates it as given in species (*τῷ εἴδει δεδομένον*). The word species is here used in its primitive sense of *appearance.*

But the term was again used by Vieta in its logical sense, as opposed to individual, in designating the algebraical notation which he first distinctly proposed. Lawyers were in the habit of describing general cases by using an individual name, as Caius or Julius, to signify any person concerned, which they termed description by species. Vieta borrowed the word to signify the use of letters to stand for numbers, when such letters were used to designate members generally, without reference to any one in particular. The logistics (a common term for the science of calculation) thus introduced he called *specious,* and his first tract on the simple operations of algebra is headed 'De Logisticâ Speciosâ.' Hence, for some time, the language of algebra was called the specious notation.

SPECIFIC ELECTRIC INDUCTION. [Electricity.]

SPECIFIC GRAVITY, or, more properly, *specific weight,* is a term used to express the weight of any gas, liquid, or solid, under some given volume; but the unit of weight and unit of volume are usually such, that for some one particular substance the weight of the unit of volume shall be expressed by the unit of weight, or by 10 times, 100 times, or 1000 times that unit. Thus the numbers expressing the specific gravities of different substances denote the actual weights of those substances under the unit of volume; and hence the ratio between the numbers expressing the specific gravities of any two substances is the same as the ratio between the weights of those substances under any two equal volumes, the density of the atmosphere and also the states of those substances with respect to temperature being the same.

Distilled water is the substance usually employed for the purpose of comparing together the weights of all substances except the gases; and because the volume of any substance varies with its temperature, in determining from experiment the specific gravity of any substance, the weight under a given volume is reduced to that which it would become at one constant temperature. The constant temperature adopted in this country is, in general, that which is expressed by 60° of Fahrenheit's thermometer.

From the experiments of Sir George Shuckburgh Evelyn it was found that at the temperature expressed by 39° Fahr., the height of the column of mercury in the barometer being 29·79 inches, the weight of a cubic foot of distilled water was 999·8066 ounces avoirdupois; and reducing this weight conformably to the table of the densities of water at different temperatures which had been given by Biot, it will be found that at a temperature expressed by 60° Fahr., and when the height of the mercurial column is 30 inches, the weight of the cubic foot of water is 999·54 ounces. But in the Parliamentary regulations, which were made in 1825, a cubic inch of water is stated to weigh 252·456 troy grains, the temperature being 62° Fahr., and the height of the barometrical column, 30 inches; and 7000 troy grains are made equivalent to one pound avoirdupois: hence it follows that a cubic foot of water should weigh 997·136 ounces. Either of these numbers is sufficiently near 1000 to make it very proper that this last should be adopted for the specific gravity of water, since a change in the value of the avoirdupois ounce, which would be scarcely appreciable in the ordinary transactions of commerce, would render the ounce an accurate and convenient unit of weight, while the cubic foot constitutes the unit of volume.

In France, since the employment of the decimal scale of weights and measures has become general, the cubic centimetre (·061028 cubic inches English) is the unit of volume, and the gramme (15·432 grains) is the unit of weight. The gramme having been determined by the weight of a cubic centimetre of distilled water of the temperature at which its density is a maximum (39°·2 Fahr.). Thus the weight of a cubic centimetre of any substance being expressed by any number *n* of grammes, *n* is the specific gravity of that substance.

The numbers expressing the specific weights of substances are also taken to represent their densities. Density, properly speaking, denotes the degree of closeness of the particles of a substance to one another; but this is evidently proportional to the number of particles within a given volume of that substance; and since the weight of a body is only the sum of the actions of gravity upon all its particles, it follows that the densities of two substances under equal volumes will be proportional to their specific gravities. It follows also that if two substances have equal densities or specific gravities, their weights will vary with their volumes; and that the weights of bodies are to one another in a ratio compounded of their specific gravities and volumes.

Previously to describing the methods of finding the specific gravities of substances, it will be proper to explain the construction of the hydrostatical balance, which is the instrument employed for the purpose. The beam of this balance rests, as usual, on the lower circumference of a circular perforation in both sides of the fork which holds it, by a pin which is fixed in it perpendicularly to its length and depth, at a small distance above the common centre of gravity of the beam, scales, and weight. The fork is suspended from the middle of a horizontal bar, and this last is suspended from a spring at the top of the pillar which supports the machine. Care is taken that the two arms of the beam are symmetrical, and that the points from whence the scales are suspended are at equal distances from its centre of gravity. Now let the substance which is to be weighed be put in one of the scale dishes, and the number of grains necessary to keep it in equilibrio be put in the other. If the weight of the substance should be an exact number of grains, that weight is determined, but if not, and it were required to ascertain the weight within one-hundredth part of a grain (for example), the following contrivance may be adopted. Suspend in a vertical position from the lower part of the scale containing the substance to be weighed, a brass wire, whose volume and weight have been previously determined, and let part of the length of this wire enter into water which is contained in a vessel underneath the scale. The scales with this wire thus attached to one of them being previously put in equilibrio when the surface of the water is at a certain mark on the wire, let the substance to be weighed be introduced into the scale above the wire, and let weights be placed in the opposite scale till one grain more would be found too great: then gently raising the whole balance till, by the increase of the weight on the side of the scale containing the substance, in consequence of a greater portion of the wire being out of the water, an equilibrium takes place. The wire being graduated so that 100 divisions correspond to a weight equal to one grain, the number of graduations on it between the surface of the water and the fixed mark before mentioned will enable the experimenter to determine the number of hundredths of a grain by which the weight of the substance in the scale exceeds the number of grains already placed in the opposite scale.

If it be required to weigh a substance in water, or in any other liquid, that substance may be suspended in a vessel containing the liquid by a horse-hair attached below the scale opposite to that from whence the wire before mentioned was suspended; and its weight while immersed in the liquid may be found to the hundredth part of a grain, as in the former case. The reason why horse-hair is employed to suspend the substance in water is, that it has very nearly the same specific gravity as that fluid.

A solid body having greater specific gravity than water being thus weighed both in air and water, may have its specific gravity determined, that of the water being supposed to be known or assumed, by the following proportion:—

> The weight lost by immersion in water (that is, the weight of water equal in volume to the volume of the solid [HYDROSTATICS]),
> Is to the weight of the body in air,
> As the specific gravity of the water is to that of the body.

$$\text{Or, }\left.\begin{array}{c}\text{The weight of}\\ \text{an equal bulk}\\ \text{of water.}\end{array}\right\} : \left\{\begin{array}{c}\text{The specific}\\ \text{gravity of}\\ \text{water}=1{\cdot}000\end{array}\right\} :: \left\{\begin{array}{c}\text{The weight}\\ \text{of the body}\\ \text{in air.}\end{array}\right\} : \left\{\begin{array}{c}\text{The specific}\\ \text{gravity}\\ \text{required.}\end{array}\right.$$

The specific gravity of a fluid is found by weighing any one and the same solid body in air, in water, and also in the fluid, and observing the two differences of weight. These differences are the weights of quantities of the two fluids which are equal in volume to the solid body; and they are to one another as the specific gravities of the two fluids: hence that specific gravity which was required may be found. [See also HYDROSTATICS.] It should be observed that the specific gravity of the solid must be greater than that of either of the fluids, in order that the solid may sink when immersed in them.

The specific gravity of a liquid may be conveniently determined by means of a *specific gravity bottle*, a light bottle containing exactly 1000 grains of distilled water at 60°, so that when the bottle is filled with the liquid whose specific gravity is to be determined, the weight in grains of the liquid immediately determines the specific gravity required. There is usually a counterpoise for the weight of the empty bottle. If such a bottle be counterpoised and then be filled with pure alcohol it will weigh only 792 grains, thus giving 0·792 as the specific gravity of the alcohol. If the bottle were filled with sulphuric acid it would weigh 1845 grains, so that 1·845 would be the specific gravity of the acid. In some cases bottles containing only 100 or 200 grains may be used with advantage.

The density of a powder not soluble in water may be ascertained by means of the specific gravity bottle, or if soluble in water spirits of wine, oil of turpentine, or some other liquid, may be employed. But suppose the powder to be sand, we weigh into the 1000 grain bottle say 150 grains of the sand. If the sand had not displaced any of the water the bottle, when filled up, would weigh 1150 grains; but it is found to weigh only 1096 grains, so that the sand has displaced 54 grains of water. Hence

54 : 1·000 : : 150 : 2·764 = the specific gravity of the sand.

If the body whose specific gravity is to be found be a solid lighter than water, there must be annexed to it, before it is weighed, a mass of some material of known specific gravity, and such that the two bodies may together sink in the water. The compound mass, and the heavier body alone, must be weighed both in air and water; also the lighter body must be weighed in air. Let W be the weight of the compound mass in air, and W′ the weight of the same mass in water; also let *w* be the weight of the heavier body in air, and *w′* the weight of the same body in water: then W—W′ is the weight of water equal in volume to the compound body, and *w*—*w′* is the weight of water equal in volume to the heavier body. The difference between W—W′ and *w*—*w′* is the weight of water equal in volume to the lighter body; therefore, by hydrostatics, that difference is to the specific gravity of water as the weight of the lighter body is to its specific gravity.

When the body is soluble in water, it may be weighed in air, and also in some fluid whose specific gravity is known, and which is not capable of dissolving it; then its specific gravity may be found by the first of the above-mentioned rules, substituting the weight lost in the fluid for the weight lost in water.

If the solid body imbibes water without being dissolved in it, let it be weighed when perfectly dry, and call that weight W: again, we find the weight of water displaced by the body when dry, and call it D; then D is to W as the specific gravity of water is to the specific gravity of the body in its actual state. But D—W is the weight of the water displaced by the solid part only of the body; therefore D—W is to W as the specific gravity of water is to the specific gravity of the solid part only of the body.

It must be observed that the true weight of any body, or that which the body would appear to have if weighed in vacuo, is greater than the weight which it is observed to have when weighed in air, by the weight of a volume of air equal to the difference between the volume of the body and that of the object by which the weight is determined. It should also be observed that the numbers expressing the specific gravities of substances are strictly correct only on the parallel of latitude passing through the place where the weight of the water under the unit of volume is determined; for the force of gravity, and consequently the weight of any substance under a given volume, increases in proceeding from the equator towards either pole of the earth.

In order to determine the specific gravity of the atmosphere, or of any gas whatever, the air or gas must be weighed in a globular vessel of glass, of sufficient magnitude to prevent the unavoidable errors of the operation from sensibly affecting the results.

In taking the specific gravities of gases, correction must be made for temperature. It is known that for every degree of Fahrenheit's scale there is an expansion equal to $\frac{1}{491}$ of the bulk occupied at 32° Fahr. If, for example, 9·2 cubic inches of gas at 70° were reduced to 60° the change in volume would be as follows:—Since 70—32=38, 491 parts of a gas at 32° would at 70° have increased in bulk 38 parts or would have become equal to 529 parts. Again 60—32=28, so that a gas which at 32° occupied 491 parts, would at 60° occupy a space equal to 519 parts. The volume therefore of any gas at 70° would bear the same proportion to the bulk which it would occupy at 60° as 529 does to 519. Hence, 529 : 519 : : 9·2 : 9·026 cubic inches. A correction is also required for pressure; but in taking the specific gravity of a gas, Regnault has reduced the number of corrections required by counterpoising the globe in which the gas is to be weighed by a second globe of equal size. The film of moisture adhering to the glass is equal in both globes, and as the bulk of air displaced is equal in both cases, the calculation for its buoyancy is thus got rid of. A balance capable of weighing 2 lbs., and turning with the 150th part of a grain when loaded, is placed on a chest, furnished with folding doors, within which the glass globes, each of the capacity of about 600 cubic inches, attached to the scale pans, are freely suspended. The counterpoise globe is hermetically sealed, the other globe is furnished with a stop-cock, the air is exhausted from it, and it is filled with the gas to be tried in a pure and dry state. The globe is again exhausted so as to get rid of the last portions of atmospheric air, when it is again filled with the gas, which may be again pumped out and again filled. To get rid of the correction for temperature the globe is placed in melting ice, which reduces the gas to the French standard; more gas is introduced to equalise the pressure, the stop-cock is then closed, the globe withdrawn and wiped carefully with a damp cloth to prevent the surface from becoming electric, and it is then attached to the scale-pan. Two hours are allowed to elapse before it is weighed, in order that it may acquire the temperature of the surrounding air and get rid of the currents about it. The weight is then accurately noted, the globe again plunged in ice, the gas removed by means of the air pump, and the elasticity of the remaining portion in the globe measured by the pump gauge. The empty globe is again weighed as before, and the difference of the two weights will give the weight of a bulk of gas the elasticity of which is equal to that of the atmosphere as marked by the height of the barometer H' diminished by the elasticity h of the remaining gas as measured by the gauge. If the capacity of the globe has been previously determined with accuracy, the corrected weight of the gas will be obtained by the following proportion :—

	The standard pressure.	The observed pressure.	The observed weight.	Corrected weight.
As	H :	$H'-h$: :	W' :	W

The following table has been calculated by Professor Miller from Regnault's experiments, and reduced to the English standard temperature and pressure.

100 Cubic Inches weigh	At 32° Fahr. Grains.	At 60° Fahr. Grains.	Sp. gr. Air=1.
Air	32·698	30·935	1·0000
Oxygen	36·153	34·203	1·1056
Nitrogen	31·762	30·119	0·9713
Hydrogen	2·265	2·143	0·0692
Carbonic acid	50·000	47·303	1·5290

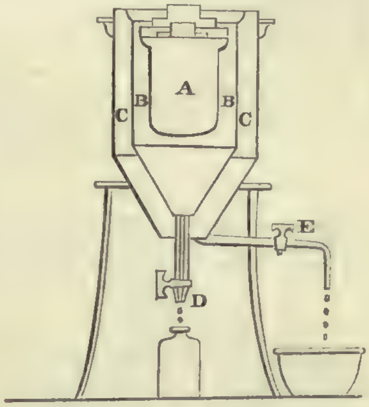
For further details on this subject, and for the method of determining the specific gravity of vapours, we must refer to Professor Miller's 'Elements of Chemistry,' Part I. 2nd edition, 1860. In the appendix to the third part of that work will be found tables of specific gravities corresponding to degrees of Baumé's hydrometer, and also of Twaddell's hydrometer, the latter being converted into their corresponding specific gravities by multiplying them by 5 and adding 1000. The specific gravities of the various solids, liquids and gases are given under their respective heads in this Cyclopædia, also in works on Chemistry. Copious tables are also published in a separate form. As a sample of such tables, a list of the specific gravities of the metals is given at the end of this article. A number of instruments on the principle of the HYDROMETER are sold in the shops, such as the *Areometer*, the *Lactometer* for testing the quality of milk, the *Saccharometer* for enabling the brewer to form an estimate of the quality of his sweet-wort, and some others. The *Barometrical Aëriometer* consists of a tall siphon tube, inverted and mounted on a pedestal with a graduated scale between the two limbs. It was intended to compare the specific gravities of immiscible liquids; thus 1 inch of mercury in one limb will balance about 13½ inches in the other limb. Brewster's *Staktometer* or *Drop-measurer* is an instrument for measuring specific gravities by the size of the drops which exude from a small orifice. The instrument is formed like a pipette, and is filled by the action of the mouth with distilled water, and the number of drops which escape between an upper and a lower level are counted, and serve as a standard. The instrument may now be filled, say with proof spirit, and the drops similarly counted. In one instrument the number of drops of water was 724, while the number with proof spirit was 2117, thus indicating that the drop of water was about three times the size of the drop of proof spirit. What are called *specific gravity beads* or hollow beads of different sizes with projecting tails, and marked with certain numbers, are used to show roughly the density of a liquid. A number of these beads being thrown into it, those which sink or swim are of no account, but those which remain just suspended indicate the specific gravity.

Metals.	Sp. gr.	Metals.	Sp. gr.
Platinum	21·5	Iron	7·844
Osmium	21·4	Tin	7·292
Gold	19·34	Zinc	7·146
Uranium	18·4	Chromium	6·81
Tungsten	17·6	Antimony	6·71
Mercury	13·596	Tellurium	6·25
Palladium	11·8	Arsenic	5·969–5·7
Ruthenium	11·4	Aluminum, rolled	2·67
Lead	11·36	,, cast	2·56
Silver	10·53	Strontium	2·54
Bismuth	9·799	Glucinum	2·1
Cobalt	8·95	Magnesium	1·743
Copper	8·92	Calcium	1·578
Nickel	8·82	Sodium	0·972
Molybdenum	8·62	Potassium	0·865
Cadmium	8·604	Lithium	0·593
Manganese	8·013		

SPECIFIC HEAT. If 1 lb. of water and 1 lb. of oil be transferred from a temperature of 40° to one of 70°, the oil will indicate 70° much quicker than the water, requiring in fact less heat to reach the same temperature. So also if these two bodies be removed from a warm to a cold atmosphere the oil will cool much quicker than the water. In comparing various bodies with water it will be found that they all vary in their rates of heating and cooling. Taking water as the standard of comparison, the thermal unit is the quantity of heat required to raise 1 lb. of pure water from 32° to 33°. And in general the quantity of heat required to raise 1 lb. of any other body from 32° to 33° is called its *specific heat*. When the quantity of heat required to raise the temperature of a body one degree is uniform throughout, or in a very large portion of the thermometric scale, the specific heat of such body is said to be uniform. Where such is not the case, it is said to be variable, and is in general found to increase with the temperature.

Three methods are adopted in *calorimetry*, as it is called, to distinguish it from *thermometry*, or the measuring of sensible or apparent heat. First, by measuring the heat by the quantity of ice which the body in question liquefies; Secondly, by calculating it by the method of mixtures; Thirdly, by observing the rate at which heated bodies cool.

By the first method the calorimeter of Messrs. Lavoisier and Laplace is used. It consists of two similar metallic vessels, one smaller than and contained in the other, so as to leave a space C C. From this space proceeds a discharge-pipe with a stop-cock E. From the bottom of the inner vessel also proceeds a pipe D; it passes air-tight through the outer vessel, and is furnished with a stop-cock. There is a third vessel, A, contained within the second, and the space B B is also filled with pounded ice. The vessel A is furnished with a cover, and there is a large tray-like cover over the whole apparatus. This is also filled with pounded ice. Now supposing such an apparatus to be introduced into a room at a temperature of 40°, it is evident that the ice in C will slowly melt, and retain B at the constant temperature of 32°. Now if we introduce the body whose specific heat is to be determined into A at any given temperature above 32°, it would cool down to that temperature, and in doing so will melt a quantity of ice, the water from which will be collected in the bottle below D. If this quantity of water be divided by the number of degrees through which the body in A has fallen, the quantity of ice dissolved by the heat corresponding to 1° will be found. This being divided by the weight of the body in A in pounds, the weight of ice dissolved by the heat which would raise 1 lb. of the body 1° will be determined. In this way it is found that the heat necessary to raise 1 lb. of water 1°, is that which would dissolve the 142·65th part of 1 lb. of ice. For other bodies we get the following rule :—Multiply the weight of ice dissolved by 142·65, and multiply the weight of the body which dissolves the ice, by the number of degrees of temperature which it loses, and divide the former product by the latter, when the quotient will be the specific heat of the body.



By the method of mixtures a mean temperature is obtained, when equal weights of the same body are mingled together; but when different fluids are mixed the result is different. For example, 1 lb. of mercury at 40° agitated with 1 lb. of water at 156°, gives a mixture =152°·3. In this case the water loses 3°·7, and the mercury gains 112°·3. Hence 112°·3 : 3°·7 : : 1 : 0·033, or, in other words, water being 1000, the specific heat of mercury is only 33; 1 lb. of water absorbing 30 times more heat than 1 lb. of mercury.

By the third method equal and similar volumes of two bodies are raised to the same temperature, and allowed to cool under similar circumstances. By observing the intervals of time required for equal volumes to fall 1°, we get the ratio of the quantities of heat which they lose. The quantities for equal weights may be inferred from the specific gravities of the bodies, and in this way the specific heats can be arrived at.

The specific heat of bodies diminishes with an increase of density, so that mere mechanical compression will raise the temperature of many bodies, and even make some of the metals very hot; iron, it is said, incandescent. The sudden compression of aëriform bodies is attended with the evolution of heat, sufficient under proper arrangements to ignite *amadou*, or German tinder. On rarefying air an opposite effect is observed, as is evident from the dimness seen on the inner surface of an air-pump receiver on first beginning to exhaust the air. The capacity for heat of the remaining air is increased, and there is not sufficient heat to retain the vapour in its elastic form. So when compressed air suddenly escapes, it absorbs heat, and moisture is deposited. Similar effects may be observed in nature. A blast of cold air descending from a lofty height, has its temperature raised by the mere compression that it undergoes.

The following are a few specific heats obtained by the process of mixture or immersion. They refer to that part of the scale between 32° and 212°:—

Water	1·00000	Brass	0·09391
Oil of turpentine	0·42593	Silver	0·05701
Charcoal	0·24150	Tin	0·05623
Glass	0·19768	Mercury	0·03332
Iron	0·11379	Platinum	0·03243
Zinc	0·09555	Gold	0·03244
Copper	0·09515	Lead	0·03140

A body in the liquid state has a higher specific heat than the same substance in a solid form. The specific heat of water, for example, is double that of ice. Indeed the large specific heat of water has a great effect on the temperature of the globe, in moderating the rapidity of the transitions which would otherwise occur.

The determination of the specific heats of gases and vapours is attended with difficulty. Regnault's results are probably very near the truth. Taking the specific heat of an equal weight of water as the unit of comparison, he finds that of air to be = 0·2377. The following are a few of his results:—

Gas or Vapour.	Equal vols.	Equal weights.	Gas or Vapour.	Equal vols.	Equal weights.
Oxygen	0·2412	0·2182	Carbonic acid	0·3308	0·2164
Nitrogen	0·2370	0·2440	Ammonia	0·2994	0·5080
Hydrogen	0·2356	3·4046	Olefiant gas	0·3572	0·3694
Chlorine	0·2962	0·1214	Sulphurous acid	0·3489	0·1553
Bromine	0·2992	0·0552	Water	0·2950	0·4750
Nitrous oxide	0·3413	0·2238	Alcohol	0·7171	0·4513
Nitric oxide	0·2406	0·2315	Ether	1·2296	0·4810
Carbonic oxide	0·2399	0·2479	Oil of turpentine	2·3776	0·5061

There is a remarkable relation between the specific heat of an elementary body and its chemical equivalent. If the specific heat of a body in the solid state be multiplied into the chemical equivalent of the same body, it gives a number which coincides almost exactly with the product obtained by multiplying together the specific heat and the equivalent of any other elementary substance.

SPECIFICATION. [PATENT.]

SPECTACLES are lenses so mounted in frames as to be conveniently held before the eyes to assist defective vision. The eyes of a person whose sight is much tried often receive injury from delay in the use of spectacles; while the sight of many persons is prematurely worn out by the use of glasses of too high a power. Whether the glasses used be concave or convex, the lowest power that is available should be used. The use of a single reading-glass instead of spectacles is injurious, since, by occasioning one eye to be more used than the other, the power and focal length of the two are rendered unequal. The unsteadiness of the glass is also a disadvantage. The defects of the single hand glass are not removed by increasing its size so much that both eyes may see through it, because in that case the axis of each pencil of rays will be distorted by passing through the lens at points beside its centre. Hand-spectacles, which are made to fold up into nearly as small a space as a single glass, are better than reading-glasses; but, although steadied in some degree by resting upon the nose, they are not equal to spectacles well fitted to and supported by the head.

Varieties in the conformation of the eyes, and in the manner and degree in which they are affected by use, render it impossible to lay down any rule for the focal length of convex glasses for persons of a given age; yet a general idea of the necessary power may be obtained from the following table, extracted from Dr. Kitchener's 'Economy of the Eyes:'—

Years of age.	Inches of focus.	Years of age.	Inches of focus.
40	36	70	12
45	30	75	10
50	24	80	9
55	20	85	8
58	18	90	7
60	16	100	6
65	14		

In some cases it is advisable to use different spectacles for night and day, to suit different degrees of light; and it is, generally speaking, well to increase the power of the glasses as the sight becomes weaker from age. Even in this, however, caution must be exercised, lest, by over-stimulating the eye, its powers be too rapidly exhausted. It should always be borne in mind, both by young and old persons, and in changing spectacles as well as in first taking to them, that the ultimate object of convex spectacles is to restore the natural power (or rather the natural *focus*) of the eye, and not to enable the wearer to see objects larger or more distinctly than with the eye in a strong and healthy condition. Short-sightedness being still less dependent upon age, cannot be met by any rule even so well as the opposite defect.

In choosing spectacles, the frame should fit comfortably to the head, and be of such a form as to bring the centre of each lens exactly opposite to the centre of the eye. Should this not be the case, the bridge or wire that unites the two halves of the frame may be stretched or bent to suit the wearer.

With respect to the glass used in spectacles, it may be taken as a rule that, except in cases where it is necessary to protect the eyes from an injurious glare of light, the most colourless material is to be preferred. The accurate figure of the lenses cannot be too strongly insisted on, and may be tested by holding the spectacles near to a printed book, and gradually moving them nearer to the eye; by doing which, if the glasses be not well-shaped, the letters will appear distorted. Veins or blebs in the glass are injurious, and may be detected by holding the glass between the eye and the flame of a candle, and moving it backwards and forwards, until it appears full of light; when every such defect will be distinctly seen. Scratches are not quite so injurious, inasmuch as they do not produce distortion; yet they should be avoided. Their diminished liability to injury by scratching forms the principal recommendation of spectacle lenses of rock crystal; but some opticians consider their use injurious, owing to their tendency to irregular refraction of the rays of light.

Several deviations from the ordinary mode of constructing spectacles may be alluded to. The *periscopic* spectacles of Dr. Wollaston were contrived in order to allow considerable latitude of motion to the eyes without fatigue, by conforming the shape of the glasses to that of the eyes. This is effected by the use of lenses either of a meniscus or concavo-convex form: the concave side being in both cases turned towards the eye. *Fig.* 1 represents in section, the form of the lens used in convex or magnifying spectacles of the periscopic construction; and *Fig.* 2 shows that of a concave lens suitable for short-sighted persons. In the former case the curve of least radius is that of the anterior, and in the latter, that of the posterior surface of the lens.

Fig. 1.

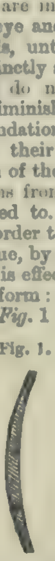
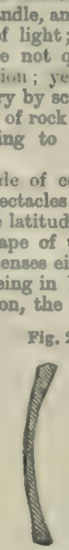


Fig. 2.



Divided spectacles, each glass consisting of two half-lenses, are sometimes used; the upper half of each glass being occupied by a concave lens, or one of very slight convexity, for seeing distant objects, while the lower half has a strong magnifier, for examining things near the eye. Such spectacles have an awkward appearance, on account of the joint along the middle, and require some practice to avoid inconvenience to the wearer; but they have been used with advantage by artists and others requiring to look alternately at near and distant objects. Other plans have been tried for obtaining a similar advantage; such as having a second pair of glasses hinged to the frame, and capable of either turning up out of the way, or being placed immediately before the ordinary lenses, to modify their power; or having two distinct pairs of spectacles, capable of being used either separately or together. Spectacles with glazed wings, or frames partly filled with crape, are sometimes used by travellers; the glasses, which may be plain, unless otherwise required, being of such a form as to shield the eyes from dust.

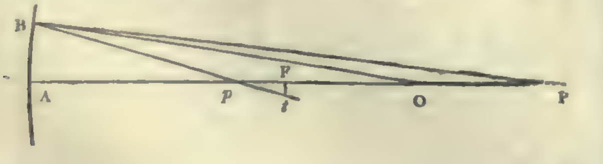
In the Great Exhibition of 1851 the British exhibitors of spectacles were contented with improvements in the method of mounting, but left out of sight the main object, the improvement of the glasses. Thus there were fine and delicate frames, some weighing only 11 grains, and the whole weight, including glasses, not amounting to more than two pennyweights. The steel frames of these spectacles resembled hair lines, and were imperceptible at a short distance. There were also ventilating eye-shades, designed to allow a current of air to circulate freely between the shade and the wearer: there were also spectacles for sketching, mounted without a rim to prevent obstruction of vision. These, with every variety of gold, silver, and steel-mounted spectacles, were to be found in abundance; but it was left to the French exhibitors to present glasses to suit almost every peculiarity of vision. M. Henri, uniting the skill of the optician with the knowledge of the physiologist, exhibited spectacles of an improved kind, the glass of which was so pure as to remove one source of uneasiness and fatigue incident upon the use of spectacles; while the foci were so arranged as to rectify certain defects and obliquity of vision. Some of these spectacles were furnished with a moveable diaphragm, to be shifted right or left at will. These were designed for the cure of squinting, either converging or diverging. M. Pouillot exhibited metallic woven spectacles for the free admission of air to the eyes, while they serve as a screen against dust, insects, &c., and also subdue the light.

SPECTRUM (in optics) is the name applied to the coloured image of the sun, or a narrow luminous object, when the light proceeding from it is transmitted through a prism, and either allowed to fall on a screen at some distance, or received directly into the eye. [Dispersion.] A similar coloured image, produced by diffraction, may be obtained without a prism [Diffraction of Light], and to it the term *spectrum* equally applies.

The fixed lines of the solar spectrum have been already mentioned in the former of the articles just quoted. Much light has recently been thrown on their origin by the labours of Professor Kirchoff. Fraunhofer long ago observed that the spectrum of a candle, or of a spirit-lamp, exhibits a double *bright* line, which *exactly coincides in position* with the double *dark* line D of the solar spectrum; and Sir David Brewster noticed a similar correspondence in the case of deflagrating nitre. ('Report of the British Association,' for 1842, p. 15.) An imitation of the fixed lines of the solar spectrum, as to their general character, is obtained by subjecting light to the absorbing action of certain gases, as was first discovered by Sir David Brewster, in the case of nitrous acid gas. If the light of a lamp, which, if unmodified, would give a continuous spectrum, be transmitted through this gas, and then analysed, the spectrum is seen to be traversed by numerous dark lines or narrow bands, which by their sharpness of definition, narrowness, and apparently capricious arrangement, remind one of the lines of the solar spectrum. That *some* of the fixed lines of the spectrum seen when the sun is near the horizon are to be attributed to absorption by the earth's atmosphere, is evident from the fact that they are not seen when the sun is high; but that *all* have not this origin seems to follow from the fact, observed by Fraunhofer, that different fixed stars have lines of their own, whereas were all the lines due to absorption in the earth's atmosphere, the same system ought to be seen whether the source of light were the sun or a fixed star.

During the researches in which he was engaged, in common with Professor Bunsen, on the application of the prismatic analysis of flames to qualitative chemical analysis, Professor Kirchoff was led to discover that flames which exhibit in their spectra bright lines of certain definite refrangibilities at the same time absorb energetically light of those precise degrees of refrangibility. (Poggendorff's 'Annalen,' vol. cx., p. 161; or 'Phil. Mag.' for August, 1860.) He further connected this phenomenon with Prevost's theory of exchanges. He found that if behind a flame giving bright lines in its spectrum were placed a brilliantly luminous body of higher temperature, giving itself alone a continuous spectrum, the compound light, consisting partly of light emitted by the flame, partly of light emitted by the luminous body behind it and transmitted through the flame, exhibited on analysis dark lines in the places of the bright lines given by the flame alone; the regions of those lines, as compared with the neighbouring regions, suffering more in luminosity by absorption of the light from the luminous body than they gained by the light emitted by the flame. A particular instance of this simultaneous emission and absorption of rays of definite refrangibility had been observed in the case of the voltaic arc many years before by Foucault ('L'Institut,' for Feb. 7, 1849), who, however, had not further followed the observation, nor connected it with the theory of exchanges. Now the outer portions of the atmosphere of the sun or a star, and the inner portions, or else the solid or liquid body itself, may be conceived to be in the same relative condition as the flame in the above experiment and the luminous body behind it; and thus we are led to connect the *dark* lines seen in the spectra of light coming directly from the sun or a fixed star, with the presence in their atmospheres, in a state of incandescence, of those elements, which, when present in flames, cause them to give out *bright* lines of the same refrangibility. It is found that the introduction of small quantities of various metallic salts into a flame causes its spectrum to exhibit bright lines, depending upon, and characteristic of, the metal introduced; and by comparing these lines with the dark lines of the solar spectrum we may infer the presence or absence of such metals therein. Thus Professors Bunsen and Kirchoff have concluded that the solar atmosphere contains potassium and sodium, that lithium is absent, or present in comparatively small quantity, and so forth.

SPE'CULUM, a name frequently given to a mirror used for any scientific purpose, as in a reflecting telescope. For the astronomical bearings of the speculum we refer to Telescope, but we here give the first part of the simpler mathematical description of a pencil of rays incident upon a mirror, so as to make this article a counterpart to Lens.



The convex mirror is comparatively of no importance, and the formulæ for it may be easily derived from those for the concave mirror, to which we proceed, referring to Mr. Griffin's work on Optics for further information. Let a pencil of rays fall on the spherical mirror A B from the point P, of which rays P B is one. Let P B be reflected into B p. It is supposed that P is in the radius O A, which is the axis of the mirror; O being the centre of the sphere. Let $AO=r$, $AP=u$, $Ap=v$. The nearer B is taken to A, the more nearly does the point p approach to a certain point F, at which the image of P is said to be formed: not that any rays are actually reflected to F, but because all the rays which are reflected from points near to A fall exceedingly near to F, which is the cusp, and brightest point of the Caustic. If $AF=w$, the position of F is determined by the equation—

$$\frac{1}{w} = \frac{2}{r} - \frac{1}{u} \ldots. (1)$$

The point p however is always nearer to A, or lies between F and A, and p F, or the longitudinal aberration, is thus found: let the length of the arc A B be y; then

$$p\,F = \frac{w^2}{r}\left(\frac{1}{r} - \frac{1}{u}\right)^2 y^2 \ldots. (2)$$

very nearly, if y be not very great. And for the lateral aberration F t, we have

$$F\,t = \frac{w}{r}\left(\frac{1}{r} - \frac{1}{u}\right)^2 y^3 \ldots. (3).$$

Again, there is for all the rays proceeding from P, after reflection, a circle through which they all pass, as in Lens. The distance of this circle of least aberration from the focus F toward A, is the following expression:—

$$\frac{3}{4}\frac{w^2Y^2}{r}\left(\frac{1}{r} - \frac{1}{u}\right)^2 \ldots. (4).$$

if Y be the whole semi-arc of the mirror: it is therefore three-fourths of the longitudinal aberration of the extreme ray. The diameter of this circle of least aberration is

$$\frac{1}{2}\frac{wY^3}{r}\left(\frac{1}{r} - \frac{1}{u}\right)^2 \ldots. (5),$$

or one-half the lateral aberration of the extreme ray.

When the rays fall parallel to each other on the mirror, u is infinite, and we have $\frac{1}{2}r$ for the value of w, $\frac{y^2}{4r}$ for the longitudinal aberration, $\frac{y^3}{2r^2}$ for the lateral aberration, $\frac{3Y^2}{16r}$ for the distance of the circle of least aberration from the focus, and $\frac{Y^3}{4r}$ for its diameter.

When $u=r$, or the incident pencil is thrown from the centre, it is returned again to the centre, and there are no aberrations.

When u is less than r, or P is between O and A, F then falls beyond O, and, as P approaches to the middle point of O A, recedes without limit. When $u=\frac{1}{2}r$, or P is at the middle point of O A, all the reflected rays are parallel to one another and to the axis of the mirror. And when u is less than $\frac{1}{2}r$, w becomes negative, or the focus is on the other side of the mirror, and the reflected rays diverge; but only the latitudinal aberration alters its sign.

The formulæ for a convex mirror may be found by making r negative in those for a concave mirror. Hence w is always negative, or the focus of every pencil is behind the mirror: the longitudinal aberrations change sign, but not the latitudinal ones: and as w has also changed sign, the effect is that p is always nearer to the mirror than F, as before.

The image in a convex mirror is always upright; and in a concave one always inverted, except when the object falls between the principal focus (or middle point of the radius) and the mirror.

The astronomical value of the speculum depends on the quantity of light that it can concentrate, and on the precision with which it forms the optical image of a distant object. Hence the magnitude, the curvature, and the surface polish are all of importance. The figure may be parabolic, where every part has the same focus, or it may be an ellipsoid, where the edge is of shorter focus than the centre, or if longer an hyperboloid. The grinding and polishing of lenses in a refracting telescope, to say nothing of the difficulty of obtaining good optical glass, greatly limit the perfection of that form of telescope; but an amount of error that would be tolerated in the best lenses, would be fatal in the speculum of a large reflecting telescope. The difficulties of forming an accurate speculum constitute a problem of the highest order, the solution of which has received the careful study of first-rate astronomers and mechanicians. The reader who is desirous of seeing how these difficulties have been overcome, will do well to consult the memoir communicated to the Royal Society of London in 1840 by Lord Oxmantown (now Earl of Rosse) entitled 'An Account of Experiments on the Reflecting Telescope.' We may also refer for a multitude of minute details to Holtzapffel's 'Mechanical Manipulation,' to papers in the proceedings of the British Association, 1843, 1850, to the 'Transactions of the Royal Astronomical Society,' to the 'Philosophical Transactions' for 1850, and also to the article Speculum in Nichol's 'Cyclopædia of the Physical Sciences,' 1860. All we can do, in this place, is to indicate the nature of the problem to be solved, and briefly to state some of the means adopted for its solution.

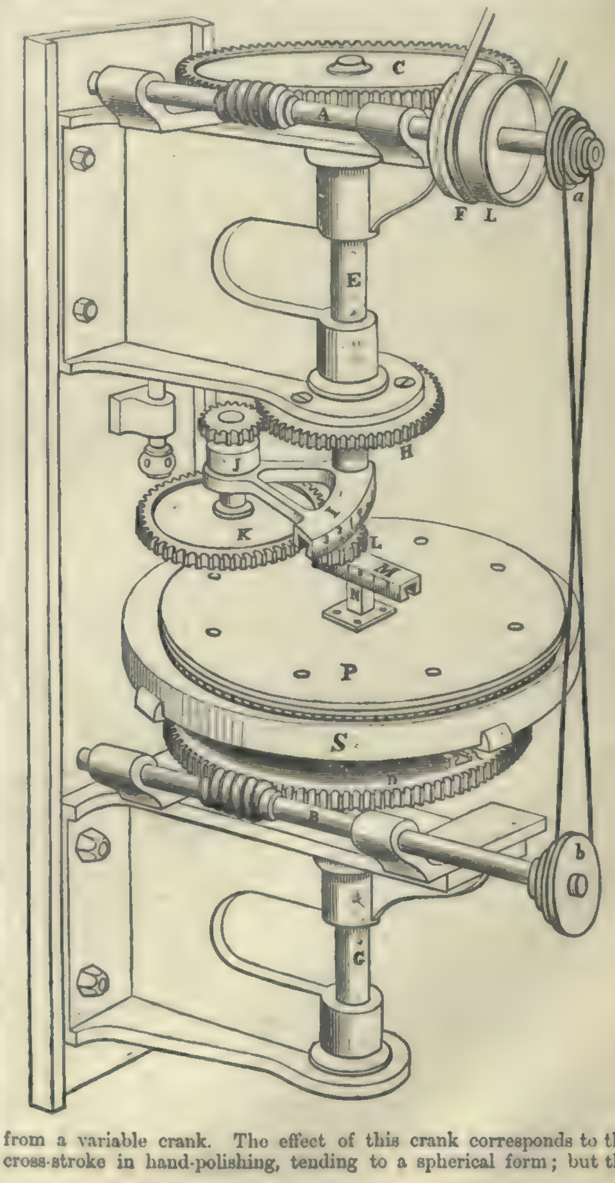
And first as to the material. Speculum metal is an alloy of tin and copper, which according to Lord Rosse should be a definite atomic compound, namely, four equivalents of copper to one of tin, or 126·4 parts of copper to 58·9 of tin, or 32 to 15 nearly. This is the alloy used by Newton in the first reflecting telescope. It is very brilliant, but so brittle as to break with a slight blow or sudden change of temperature, and so hard and friable that it cannot be worked with steel tools. The introduction of other metals or a larger proportion of copper may diminish the brittleness, but will lower the brilliancy, and produce a metal more liable to tarnish. It is remarkable that speculum metal displays its porosity with the aid of a simple Coddington's microscope. [BRONZE; SPECULUM METAL.]

When it is stated that the 6 feet speculum of Lord Rosse's telescope weighs 4 tons, it may be imagined that the casting of such a mass is a work of some difficulty. If a close mould were used, or if the metal were rapidly cooled, it would fly to pieces in attempting to work it, or if cast in sand, as an open casting, it would probably have a spongy or crystalline texture, which would be visible when polished. Small specula are cast in sand, and as soon as they are set the sand core is pushed out of the central aperture of such as are intended for Gregorians, and the red-hot disc is surrounded by ignited wood ashes to delay the cooling; but in large specula the margins solidify first and from want of ductility the central parts are torn away in the act of contracting, and the mass becomes rent or flawed. To prevent these defects and accidents, the speculum is cast on a *chill* or surface of iron moderately heated, the effect of which is to give a fine grain and increased compactness to the metal to a small distance from the surface. In Mr. Lassell's mode a cast-iron mould a little deeper than the speculum, with its bottom convex, and of the same radius, is attached to the end of a strong weighted lever, so that when the mould is empty, its bottom makes a considerable angle with the horizon, but becomes horizontal when charged with the proper quantity of speculum metal. The fused metal is poured into a lateral cell, communicating with the mould at its lowest point. In this way the metal rises smoothly and evenly along the bottom, and entangled air and scoria are got rid of. In Lord Rosse's arrangement the bottom of the mould is made of pieces of hoop iron on edge, wedged tightly in an iron frame, and turned to the proper curvature. This holds the fused metal, but allows the gaseous matter to pass freely through. On this a wooden pattern is laid about twice as deep as the intended speculum and 1-65th larger to allow for contraction: sand is rammed round this, and when the pattern is removed and the metal poured into the cavity, the lower surface is chilled, the sides in contact with the sand next harden, while the central parts remain longer fluid, and the top or back of the speculum congeals last, by which arrangement the contraction and irregularity of texture occur where they are least injurious. While the cast is still red-hot, in which state it is not brittle, it is transferred to an annealing furnace, which has been kept heated for some days so that its interior brickwork is at a full red, and here it is left to cool for a month or six weeks in case of a 6-feet speculum; smaller ones, of course, requiring less time.

The grinding and the polishing, so as to produce a brilliant polish and a true parabolic figure, are still more difficult than the casting. The grinding is done by means of a tool on which are cemented small pieces of gritstone, dressed to the convexity of the surface by means of a gauge of sheet-iron. A convex and a concave gauge should be at hand: circular arcs are struck on them of a radius equal to twice the focal length, and afterwards left free by filing and grinding. When an even surface is produced by this tool, another is taken, of cast-iron, turned to the convex gauge, and cut up into small squares by two sets of grooves, about a quarter of an inch wide. This is charged first with sand, then with emery and water, and is made to traverse the face of the speculum by machinery. There must be occasional washing, and emery of increasing fineness used, till all scratches are removed. The face may be tested optically from time to time, and examined as to the focus. Early in the process the edge of the speculum is ground true with sand applied by means of a divided hoop of iron, which admits of being tightened. The back may also be made uniform. In the grinding, care was taken to prevent the slightest jar of the grinder on the speculum, as the metal is so brittle that there is great danger of breaking it. A number of thin wooden wedges may be placed on the margin of the speculum, and the polisher slowly lowered upon them, and then by degrees they can be gently withdrawn.

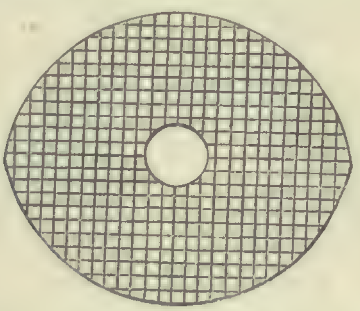
In the polishing process, the tool, sometimes of lighter material than the grinder, is coated with pitch to a small thickness, but not closing the grooves which divide the surface into squares. The pitch must be of the degree of hardness such that a sovereign will stand on it on edge for one minute, and leave the impression of four nicks of the milling. The speculum is cleaned from emery or dust, and properly secured on the polishing-machine, and is smeared with a mixture of water and rouge (peroxide of iron), and the polisher, at the temperature of 80°, is placed on it for a short time. On raising it, all the squares of the pitch must have been in full contact with the speculum. If this be the case, the polisher is ready for work. In the old method of polishing by hand, the polisher is fixed to a firm block, and the operator, holding the speculum by a handle cemented to its back, works it backwards and forwards across the polisher by straight strokes, after a few of which he shifts his position to give them a new direction, turning the speculum somewhat to get rid as far as may be of inequalities in the abrasion; and from time to time these cross-strokes are varied by circular ones; and as the moisture evaporates, a little water must be supplied at the edge. The adhesion and friction increase rapidly; the polishing-powder changes in colour, and at last disappears, when a fine polish covers the speculum, and the operator, by a few circular strokes, completes the parabolic figure.

This may be tested by optical means. Care must be taken not to pass the proper figure, for it cannot be recovered except by re-grinding and repeating the whole process. The advocates for this laborious kind of work attach much importance to the touch of the operator, since he can *feel* if anything is going wrong, and correct it in time. But as hand-polishing cannot be applied to specula above nine inches, and science required those of larger size, the introduction of machinery was necessary to progress. The two Herschels availed themselves of mechanical aid; but the first astronomer who has given a minute account of his method is Lord Rosse, in the paper above referred to. His plan is to work by a double system of cross-strokes, while the speculum and polisher are slowly revolving with unequal velocities. The speculum is carried by a chuck attached to a strong vertical shaft, and is surrounded by water at 55° to insure the proper consistence of the pitch. The polisher is of iron, stiffened by means of ribs arranged like the walls of a honeycomb, and suspended by six points to lessen the chance of bending. The polishing-bar has a rectilinear motion from a variable crank. The effect of this crank corresponds to the cross-stroke in hand-polishing, tending to a spherical form; but the

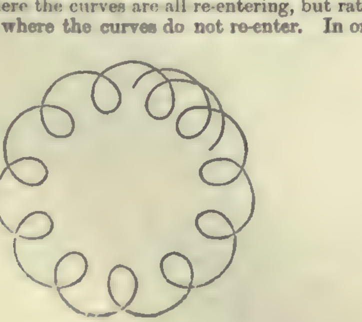


rotation of the speculum tends to lengthen the focus of the exterior zones of its surface. There is also an excentric motion, which augments to any required extent the circumferential action. The figure depends on four things, namely, the radius of the primary, that of the excentric, and the angular velocities of it and the speculum. In polishing a six-feet speculum, the number of strokes is eight per minute; and for smaller ones, inversely as their diameter. The polishing of a six-feet speculum requires five hours. The figure of the speculum was tested in Lord Rosse's process, during the grinding and polishing, by observing the reflection of a watch-dial placed perpendicularly over the speculum, at a height of about 90 feet. By carefully watching the image of this dial, the adjustment of the length of stroke could be made with such accuracy that the three-feet speculum, with its whole aperture, was thrown perceptibly out of focus by a motion of the eye-piece amounting to less than the thirtieth of an inch. During the polishing, it was found necessary, in order to prevent irregular expansion of the speculum, to maintain a uniform temperature in the polishing-room; and it was also necessary to have a certain degree of moisture in the air, that the wet polishing-powder should dry at the proper rate. When the air was too damp, the polishing was not attempted; if it were too dry, a jet of steam was introduced. Instead of water, ammonia soap (or common soap treated with ammonia) was sometimes used with the polishing-powder, as this was found to dry more rapidly.

A more complete idea of the arrangements for grinding and polishing specula may be formed from Mr. Lassell's arrangement, as improved by Mr. Nasmyth, and represented in the figure (col. 704), the object being to imitate as closely as possible those evolutions of the hand by which Mr. Lassell had been accustomed to produce perfect surfaces on smaller specula. F L represent fast and loose pulleys for conveying the power, and transmitting it by the endless screw on the shaft, A, to the wheel C. The spindle, E, of this wheel has attached to it a crank or arm, I, which carries a pinion, J, and causes the pinion to revolve round the toothed circumference of the wheel H, which wheel H, being fixed to a bracket, causes the pinion J to revolve with as many turns as its circumference is less than that of the wheel H, or five to one. The spindle of the pinion J has a wheel, K, fixed to it at its lower end, which wheel K, in like manner, conveys motion to the pinion L, which works on an adjustable centre-pin; and as the T-groove in which the centre-pin of L works is radial to the centre of the wheel H, this pinion may be set to any degree of excentricity, and yet be in gear with H. The pinion L has also a cross-crank, M, attached to its under side, which, having its crank-pin, N, also sliding in a T-groove, it may be set to and fixed at any degree of excentricity; so that by these two excentric movements we have the means of giving to the pin N any compound motion required. The polisher is of wood or other suitable material, coated with pitch, and divided into squares.



This polisher is free to move upon the pin N, while N causes the polisher to slide over the surface of the speculum S with a motion not like that represented in the figure contained in Holtzapffel's 'Mechanical Manipulation,' where the curves are all re-entering, but rather as in the following figure, where the curves do not re-enter. In order that



every part of the surface of the speculum may continually change its position, with respect to the movements of the polisher, a slow revolving motion is given to it by an endless screw on B working into the teeth of the wheel D, which forms the base on which the speculum rests. It rests, in fact, on nine equilibrium points in the cell in which it is to rest when actually in the telescope, so as to incur no risk of distortion. "By means of this arrangement," says Mr. Nasmyth, "a speculum having a decidedly hyperbolic figure may be corrected, and brought to a perfect parabola, or to a spherical curve, or the same may be done in the reverse order, at pleasure." In Lord Rosse's arrangement, the polisher is traversed over the speculum with reciprocating longitudinal motion; and in Mr. Lassell's, the polisher has a continuous epitrochoidal motion, the path of which is dependent upon the adjustments of L and M. The polisher is made of two thicknesses of pine-wood, with the grain crossed. This, from its lightness, does not require to be counterpoised, as in Rosse's; and, apparently from its being sufficiently yielding to accommodate itself somewhat to the form of the speculum, a single coating of pitch was found sufficient, and the polishing was completed with wet powder. The value of the two-feet speculum thus produced is shown by Mr. Lassell's discovery of the satellite of Neptune, an eighth satellite of Saturn, and the re-observation of the satellites of Uranus, which had not been seen since their announcement by Sir W. Herschel. Mr. Lassell's polisher has served as a type to other skilful mechanicians, such as Mr. De la Rue, Mr. Grubb, of Dublin, and Mr. Lassell himself has introduced some modifications.

Further details respecting specula belong to TELESCOPE; but we may mention the proposal, if not introduction, of silver as a substitute for speculum metal. It reflects 0·91 of the incident light, while speculum metal only reflects 0·67. It is, on the other hand, liable to tarnish, and there are difficulties in the way of figuring and polishing it. M. Foucault, however, has formed a speculum of glass, figured and polished to a true parabola, and deposited a thin but uniform film of silver on its surface, by means of Drayton's process, in which a solution of nitrate of silver is reduced by means of oil of cassia. The exterior surface of the glass speculum is parabolic, but has no lustre. That property may be imparted to it in a high degree without any sensible change of figure, by means of light friction with wash-leather and a little peroxide of iron. In case of tarnish, the polish may be renewed by the same process, and often be repeated before the silvering requires to be renewed.

SPECULUM METAL. [BRONZE.]

SPEISS. [COBALT.]

SPELTER. [ZINC.]

SPERMACETI, or CETACEUM, a fatty material, obtained from the *Physeter macrocephalus*, (*Catodons macrocephalus* of Beale) [CETACEA, in NAT. HIST. DIV.], a species of whale, generally met with in the South Seas, but also on the coast of Greenland, and occasionally stranded on the coasts of Britain. When purified it is called *cetine*. It is also soluble in ether, and volatile and fixed oils. It has a white, pearly, or silky appearance, considerable tenacity, but may be broken into mica-like scales, with a smooth or fatty feel, slight fish-like odour, and mild mawkish taste. Its specific gravity is ·943; it melts at 112°, and when a lighted body is applied to it, it burns with a clear flame.

Sulphuric is the only acid which dissolves it. It is only partially dissolved by the fixed alkalies, and is with difficulty saponifiable. Hot caustic ammonia forms with it an emulsion, which is not decomposed on cooling.

Long exposure to the air renders it rancid; it may be again purified by washing in a warm ley of potass. It should be protected from air and light.

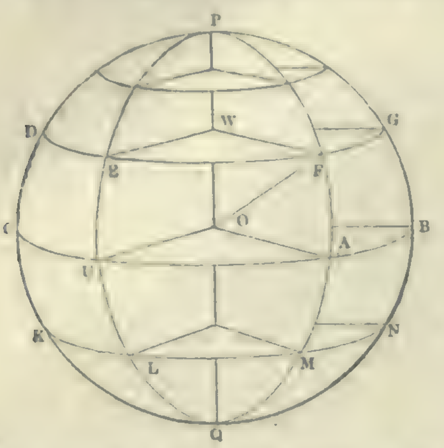
A hundred parts of spermaceti consist of sixty parts of margaric and oleic acids, forty parts of ethal, and 0·9 parts of a yellow extractiform substance. The ultimate composition of cetine seems to be—carbon, 81; hydrogen, 12; oxygen, 5.

Spermaceti possesses the properties common to fatty matters. It is bland and demulcent, with considerable nutritive qualities, when taken internally. It was formerly much used in colds and coughs, united with mucilage or syrup, to shield the throat from the irritation of the air, also in dysentery. Triturated with sugar-candy, and having warm milk added to it, it is a mild nutrient article, fit for children or old persons. It is however now chiefly employed externally as an ingredient in ointments and cerates. It is also largely used to form candles, and to burn in lamps.

SPHERE, or GLOBE, a solid body, the surface of which is everywhere equally distant from a given point or centre within it. This distance of each point from the centre is called the radius. In the article MENSURATION will be found the formulæ which connect the surface and solidity of a sphere with the radius: we shall here add that the weight of a sphere of pure water is found in ounces avoirdupois, by multiplying the cube of the number of inches in the radius by 2·4171; and in pounds avoirdupois by multiplying the cube of the number of feet in the radius by 261·05. These results multiplied by the specific gravity give the weight of a sphere of any other substance.

A section made by a sphere and plane is always a circle. When the cutting plane passes through the centre of the sphere, this proposition is obvious from the definition of a circle. When the plane does not pass through the centre the assertion follows so soon as it is shown that a plane curve having all its points equidistant from a given point *not in the plane* is a circle. A section passing through the centre is called a *great* circle, and one which does not pass through the centre a *small* circle. These terms are incorrect, since a small circle may be in size as nearly as we please equal to a great circle: the words *greater* and *smaller* would be more correct.

The centre of a circular section is found by drawing a perpendicular from the centre of the sphere to the plane of the section. All sections whose planes are parallel have their centres on one straight line, namely, the perpendicular to the planes which passes through the centre of the sphere. The great circle in such a system (C U A B) is called the *primitive*, the common perpendicular (P O Q) the *axis*, all the small circles (D E F G, K L M N, &c.) *parallels*, the extremities of the axis



(P and Q) *poles*, and all great circles passing through the axis and poles (P C Q B, P U Q, P A Q, &c.) *secondaries.*

By the angle made by two great circles is always understood the angle made by their planes, which is also that made by their tangents at the point of intersection, and that made by the intersections of the two circles with the third circle to which both are secondary. It is also the angle made by the axes of the two circles. Thus the spherical angle E P F is the angle made by the planes P E Q and P F Q, or the angle made by tangents to the circles drawn through P, or the angle U O A.

The angle made by two straight lines drawn from the centre (as O A and O B) is often confounded with the arc (A B) which that angle marks out on the sphere. When this causes any confusion, which at first it will sometimes do, instead of each arc mentioned, read its angle: thus for the arc A B read the "angle subtended by the arc A B" or A O B. Thus when we say that the angle made by two great circles is the arc intercepted between their poles, we mean not to equate the angle to the length of an arc, but to the angle which that arc subtends at the centre.

The following propositions are essential to the doctrine of the sphere in geography and astronomy; they may be easily proved, and will serve as exercises in the meaning of the preceding terms:—

1. If the poles of a first circle lie upon a second, the poles of the second will also lie upon the first.

2. If a sphere be made by the revolution of a semicircle round its diameter, the diameter will be an axis, the middle point of the semicircle will describe the primary, all other points will describe parallels, and every position of the generating circle will be a secondary.

3. If a point on a sphere be distant from each of two other points (not opposite) by a quadrant of a great circle, the first point must be a pole of the great circle which joins the second and third.

4. The arc of a parallel (as E F) is found from the corresponding arc of the primary (A U) by multiplying the latter by the cosine of the angle (F O A) which is subtended by the intercepted arc (A F) of the secondary.

5. The surface of the zone intercepted between any two parallels is the rectangle contained under the circumference of the primary and the perpendicular distance between the parallels.

6. The surface of a lune contained between two great circles is such a proportion of the whole surface of the sphere as the angle contained between the two great circles is of four right angles.

7. The part of a lune contained within any zone made by two of its parallels (as E F U A) is such a proportion of the whole zone as the angle of the circles forming the lune is of four right angles.

We are now to show the method of Co-ordinates by which points in the sphere are ascertained, and their relative positions described. Take any great circle C U A B, and choose any point U as an origin, and either direction to be that in which arcs are measured. Say for instance that U A, in preference to U C, shall be the direction in which arcs are measured. The position of any point in this great circle is then ascertained simply by determining its distance from U, since there is a tacit understanding as to the direction in which that distance shall be measured. If we give a name to that distance, be it longitude, right ascension, or any other, the point whose right ascension (if it be right ascension) is 80° means the point which is at 80° distance from U in the direction U A. Again, if we wish to describe any other point, not in the great circle chosen, as F: through F draw a secondary to the great circle (P F A Q), then the point F will be known as soon as A is described, in the manner just laid down, and also as soon as the arc A F is given, and the pole towards which it is measured. These two co-ordinates, U A and A F, when described in magnitude and direction, form a complete description of the position of the point F on the sphere; and the angles subtended by U A and A F are generally used instead of U A and A F.

For the first steps of the application of spherical geometry to astronomy, see the next article.

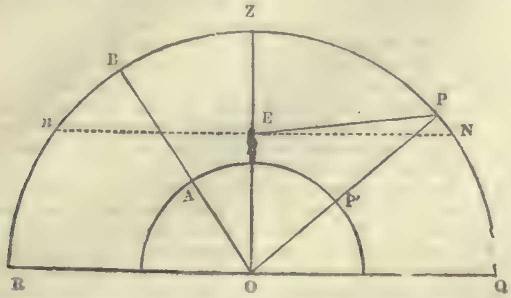
SPHERE, DOCTRINE OF THE. This phrase is generally used to signify the application of the simple geometrical notions in the article Sphere to geography and astronomy. It comes between spherical trigonometry and those two sciences, being merely the explanation of the circumstances under which the former is to be applied to the latter, and the nomenclature which is employed to facilitate explanation.

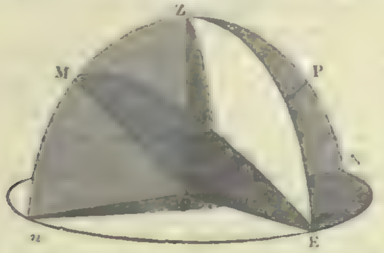
In geography the end is almost gained when a distinct notion is acquired of the meaning of the terms terrestrial latitude and terrestial longitude, generally abbreviated into latitude and longitude. These are only names given to a pair of spherical co-ordinates as described in Sphere, the axis of rotation of the earth furnishing the means of prescribing the necessary data. The earth revolves round an axis, say P Q (see the diagram in Sphere), and the great circle perpendicular to that axis is the *equator* (C U A B). An arbitrary point U is chosen as an origin; and P being the pole which is called north, U A is the east direction and U C the west. The English choose the point U in such a way that the secondary P U passes through the Observatory at Greenwich: the French pay the same compliment to their Observatory at Paris, and so on. The co-ordinate U A (or its angle) is called longitude, east or west according as it falls; and the co-ordinate A F (or its angle) is called latitude, north or south according to the pole towards which it is directed. Thus the place F (P U passing through Greenwich) would be described as in longitude U A east of Greenwich, and F A of north latitude; but if the fundamental secondary, P U, be moved any number of degrees to the east, every east longitude must be diminished and every west longitude increased as much; and all places which the secondary passes over in the transfer, must have the names of the directions of their longitudes changed, and take for their new longitudes the excesses of the angle of transfer over their former longitudes. Again, longitude might be measured all the way round in one direction: thus D, instead of being described as in U C of west longitude, might be considered as in 360° − U C of east longitude.

There are few problems of much interest connected with geography merely; and it must be remembered that the common terrestrial globe, with its brazen secondary to the equator (called a meridian, very incorrectly, except as meaning that it *may be made* a meridian to any place), its ecliptic, and figured horizon, is almost as much a representative of the sphere of the heavens as of the earth; and the most useful problems are those in which the sphere is used conjointly in these capacities. But, merely to show what we asserted at first, that the description and nomenclature which are called the doctrine of the sphere are nothing but the connecting link of geography, &c., and spherical trigonometry, let us ask the following question:—Given a table of latitudes and longitudes, required the distance between two places mentioned? Let D and M be the places (see diagram in Sphere), then P D is the co-latitude of D, or 90° − lat. of D, and P M (on account of M's south latitude) is 90° + lat. of M; while the spherical angle, D P M (which is the angle of the arc A C), is, on account of the longitudes being of different names, the sum of the longitudes of D and M. Hence, if D and M be joined by the arc of a great circle, we have given (from the tables) two sides and the angle included, in the spherical triangle D P M. From these data the third side, D M, can be found, in degrees, &c.: convert this into miles, at the rate of 69 miles to a degree (which is accurate enough for the purpose), and the result will be the distance required.

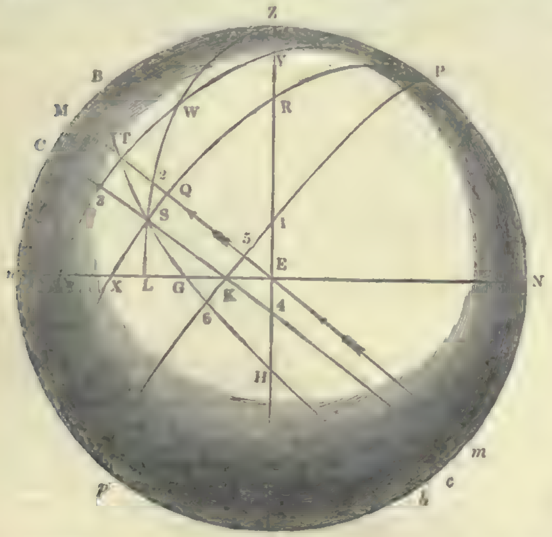
We now make the passage from the terrestrial to the celestial sphere. The latter is a fiction, derived from the impossibility of distinguishing the distances of the heavenly bodies, on which account they all seem at the same distances, on a sphere so great that the earth, its centre, is but a point in comparison. But it must be remembered that the appearances of the heavenly bodies conform themselves to this fiction, so that the development of the consequences of the latter amounts to an explanation of the phenomena of the heavens. And first, the rotation of the earth from west to east gives to the sphere of the heavens an apparent motion from east to west, round an axis which is obtained by lengthening the axis of the earth. The point of the heavens which answers, for the moment, to the spectator's position on the earth, is that point which is directly over his head, or his *zenith*. And since the spectator is not exactly at the centre of the celestial sphere, we give the following diagram, illustrative of the manner in which the effect of this misplacement is destroyed by the largeness of the sphere.

The eye of the spectator is at E, and his zenith-line is O′Z. The smaller circle is a section of the earth, and the larger of the sphere of the heavens. The figure is drawn of dimensions so false, that the sphere of the heavens is represented about as well as a common orrery represents the solar system. The Horizon is the small circle drawn perpendicular to O Z through N S; the altitude of the pole of the heavens (P′ being that of the earth) is the angle N E P. Now suppose the earth and the spectator to diminish until they cannot be distinguished from the point O, the sphere of the heavens remaining the same. All angles at O remain unaltered: the altitude of the pole of the heavens becomes Q O P, equal to the angle A O E, the latitude of the spectator, and the horizon of the latter coincides with the great circle drawn through R Q perpendicular to O Z. The great circle, Q P Z R, passing through the pole and the zenith, is the *meridian;* the secondary to the horizon perpendicular to the meridian is the *prime vertical.* We here exhibit a skeleton of the sphere, showing *n* M Z P N, half the meridian; N E *n*, the horizon (N, E, *n*, its north, east, and south points); Z E, the prime vertical; a portion of P O, the axis; E M, the equator, perpendicular to the axis.

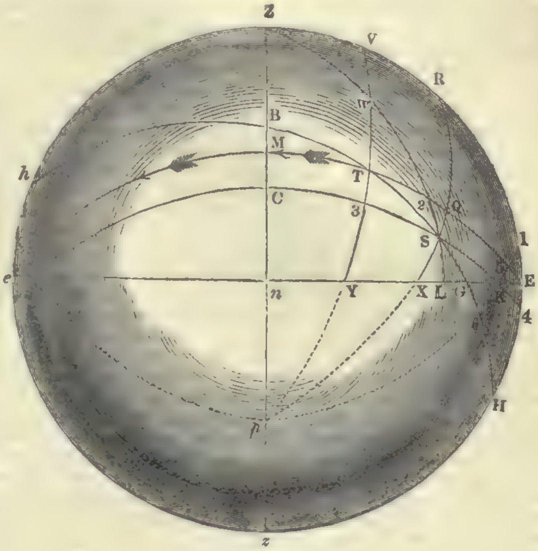


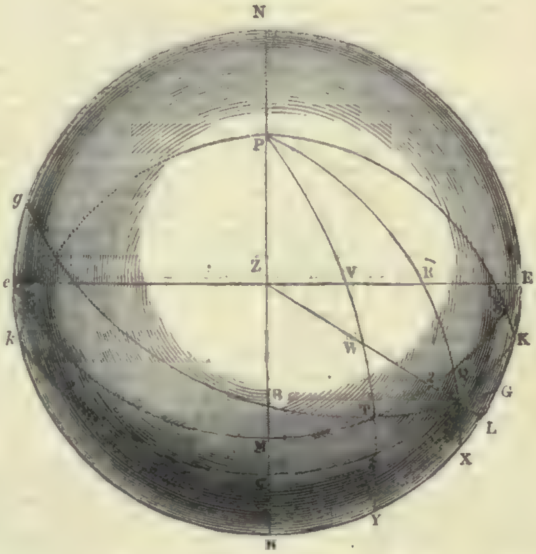


We now give three positions of the sphere, differing only in the manner of projecting the figure. Each one represents the state of the heavens some two or three hours before noon in an October morning, in a latitude somewhat greater than our own. The first figure is projected on the plane of the meridian; that is, the meridian is the circle which bounds the view of the sphere. The second is projected on the prime vertical; the third, on the horizon.



The diagrams have many letters and numerals which are useless, except in tracing the affinities of the figures. The meridian, *n* P Z N; the prime vertical, Z E *z*; the horizon, *n* E N, and its poles, the zenith and nadir, Z and *z*; the equator, M E *m*, and its poles P and *p* (which are called *the* poles, from their importance), are supposed to be well known. The reader who is new to the subject should learn to see the following propositions *in each of the figures*, namely:—the poles of the meridian are the east and west points of the horizon; the poles of the prime vertical are the north and south points of the horizon; the equator and prime vertical make an angle equal to the latitude of the place of observation (which is P N, or the angle of P N); the equator and horizon make an angle equal to the colatitude (90°—lat.) of the place of observation; a star which is distant from the north pole by less than the latitude of the place of observation can never set nor go below the horizon (it is called a *circumpolar* star).





The diurnal motion carries the sphere round the axis in the direction of the arrows marked upon the equator. The meridian, horizon, and prime vertical, must be considered as detached from the sphere, and not moving with it. Every point of the sphere describes a small circle parallel to the equator: and all stars which are at the same distance from the pole describe the same small circle. The whole revolution takes place in what is called a *sidereal* day [TIME], about four minutes less than the *mean solar day* shown by a good clock. A secondary to the equator describes angles uniformly about the pole at the rate of 360° to 24 sidereal hours, or 15° to 1 sidereal hour. [ANGLE.] Hence if we would know how long it will be before the diurnal motion will bring a star at K into the position S, we must turn the angle S P K, which is measured by the arc Q 5, into sidereal time at the rate of 15° to 1^h, and then turn the sidereal time so obtained into common clock time, at the rate of about 23^h 56^m of clock time to 24^h of sidereal time. For purposes of general explanation, the two species of time may be confounded. The sidereal day is always made to begin when a certain point of the equator, presently to be noticed (the vernal equinox), comes on the south side of the meridian, and the hours are measured on to 24^h.

We shall now explain the systems of co-ordinates which are made use of in describing the positions of stars.

1. *Horizontal System. Altitude and Azimuth.*—In this case the horizon is the primitive circle employed; its north point, N, is the origin, and the position of a point W is determined by its azimuth, N I, and its altitude, L W; Z W L being a secondary to the horizon. Since the altitude and azimuth are reckoned by means of a fixed circle, both

are perpetually changing their values for any one star. The following assertions will serve to try the reader's comprehension of these terms:—points on the north side of the meridian are in azimuth 0°, on the south side in azimuth 180°; the zenith has all azimuths, and every other point of the east side of the prime vertical 90° of azimuth; the altitude of a star which sets is greatest when it is on the meridian; the meridian altitudes of a circumpolar star are the greatest and least of all its altitudes, and their half sum is always the latitude of the place of observation. [ALTITUDE; AZIMUTH.]

2. *Equatorial System. Right Ascension and Declination.*—The primitive circle here is the equator; the point of the equator called the vernal equinox (presently described) is the origin, and the direction of the sun's motion from west to east is the direction in which *right ascension* is measured. In the diagrams T is not the vernal, but the autumnal equinox, the point opposite to the vernal equinox, consequently T has 180° of right ascension, and so have W, V, and all points on the same half of the secondary PWT. The other co-ordinate, *declination*, is measured on the secondary to the equator north or south according to its direction: thus S has for its right ascension 180° + TQ, and QS of south declination; while R has the same right ascension, and QR of north declination. The secondaries to the equator are called *hour-circles*, and the difference of the right ascensions of two stars is the angle made by their hour-circles: thus the angle QP5, measured by the arc Q5, is obviously the difference of the right ascensions of the point R and 1. The equator moves with the sphere, so that the right ascension and declination of a star remain the same, as long as it moves only with the diurnal motion. The right ascension is generally expressed in time, as before described; and the following assertions will serve for exercise in the meaning of these terms:—the sidereal day beginning when the vernal equinox is on the meridian, the right ascension of any star, turned into time, expresses the moment of the sidereal day at which that star will be on the meridian; when the vernal equinox is on the meridian of Greenwich, the longitude of any place, measured eastwards, is the same as the right ascension of a star which is on the meridian of that place; the meridian altitude of any star, diminished by its declination (if north), or increased by its declination (if south), is the co-latitude of the place of observation; every star which has the same declination as the place of observation has latitude, passes directly over the head of the spectator at that place; the time of rising of a star, and the time during which it remains above the horizon, depend solely upon the declination, and not at all upon the right ascension. [RIGHT ASCENSION; DECLINATION.]

3. *Ecliptic System. Celestial Longitude and Latitude.*—The ecliptic (BTS*b*) is the circle which the sun appears to describe in the course of a year, the direction of this *orbital* motion being from west to east. One half of it is north, the other half south, of the equator; and the point of the equator in which the ecliptic cuts it, and through which the sun passes when it leaves the southern and enters the northern part of the ecliptic, is the *vernal equinox*, the opposite point being the autumnal equinox. Consequently, T, as drawn, is the autumnal equinox, for motion from west to east, or in the direction BTS, makes the sun pass from the northern to the southern side of the equator. In this system of co-ordinates the ecliptic is the primitive circle, the vernal equinox is the origin, longitude is measured from west to east on the ecliptic, and latitude north or south, as the case may be, is measured on a secondary to the ecliptic drawn through the star. In fact, celestial longitude and latitude are to the ecliptic precisely what right ascension and declination are to the equator. The *obliquity* of the ecliptic is the angle made by the equator and the ecliptic; and the secondaries to the ecliptic, drawn through the vernal and autumnal equinoxes, are the equinoctial and solsticial colures. [LONGITUDE AND LATITUDE.]

A complete understanding of all these terms makes the comprehension of the globe easy, and also the application of spherical trigonometry to those who know the latter science. We now describe the diagrams, in order to point out how such applications are made. The point S is the sun, of course in the ecliptic; its right ascension is 180° + TQ, its declination QS south, its longitude 180° + TS, its latitude 0°, its azimuth NL, its altitude LS, its *hour-angle* (a name given to the angle made by the hour-circle of a star with the meridian) SPM, measured by MQ. The parallel to the equator CSK*c* would be the diurnal path of the sun, if it continued at the point S of the ecliptic; but as the sun has a slow motion of its own towards K, it is not strictly (though very nearly) correct to say that, for the day in question, the sun continues in the parallel. Hence we may say, without sensible error, that the sun moves over *c*K during half the night, and through KC during half the day. It rises when at the point K, and the angle KPS, turned into time, shows the sidereal time elapsed since the rising, while the angle SPM shows the time which is yet to elapse before noon. As to the time of the year, observe that the sun was at the autumnal equinox T on the 21st of September, since which time it has moved over TS, independently of the diurnal rotation of the sphere. We see then what is meant by saying that the diagram represents some morning in October. The use of the globe is thus explained, as far as setting it for any hour and day is concerned. The pole P must first be elevated until the elevation is equal to the latitude of the place, the sun must then be put in its proper place in the ecliptic for the time of the year, and its hour-angle must then be made to represent the time which is wanted of noon, or has elapsed since noon. All this on the globe is done without attending to the distinction of sidereal and solar time, which need hardly be attended to when no greater degree of accuracy is wanted than can be obtained on a globe. We now refer the reader to works on the use of the globes, and shall conclude this article by a few indications of the mode of applying spherical trigonometry.

To find the time of sunrise, observe that in the spherical triangle PKN, right-angled at N, we have PK given, being 90° + the sun's declination, and also PN, the latitude of the place of observation. Hence the angle KPN can be found, which being turned into sidereal time, gives a good approximation to the time of sunrise, refraction and the sun's proper motion being neglected.

Given SL the sun's altitude, and the latitude of the place; required the time of day. In the triangle SZP, we now know ZS the sun's co-altitude, SP which is 90° + declination, and ZP the co-latitude of the place. Hence the angle SPZ can be found, and thence the time from noon. If S, instead of the sun, were a known star, the question would be solved in the same way, except that the sun's hour-angle is no longer SPZ, but that angle increased or diminished by the difference of the right ascensions of the sun and star.

Two known stars, W and S, are observed to be in the same circle of altitude SWL at a given place; required the time of day. Here PW and PS, the co-declinations of the stars, are known, and also the angle WPS, which is the difference of their right ascensions; hence in the triangle SWP the angle SWP can be found, and thence its supplement, the angle ZWP. Then, in the triangle WZP, we know the angle ZWP, PW the co-declination of the star W, and ZP the co-latitude of the place: whence the angle WPZ can be found; and thence, by comparison of W with the sun, the time of day.

For the actual applications we must refer to mathematical works on astronomy.

SPHERICAL ABERRATION. If a lens or mirror could accomplish all that we should desire in it, it would refract or reflect rays diverging from or converging towards a point so that the directions of the refracted or reflected rays should accurately pass through a point. This however can in general be only approximately effected; and the failure of the rays to pass accurately through a point is termed *aberration*. It depends partly on the form of the surfaces, partly on the compound nature of light itself. The former is termed *spherical*, the latter *chromatic aberration*. Spherical aberration is of course the only kind which exists in the case of a mirror. For the formulæ relating to the spherical aberration of lenses and mirrors, see LENS and SPECULUM.

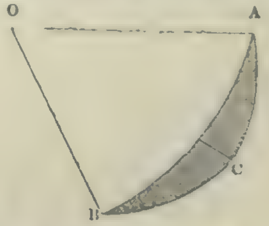
SPHERICAL ANGLE. [SPHERICAL TRIGONOMETRY, &c.]

SPHERICAL EXCESS. [SPHERICAL TRIGONOMETRY, &c.]

SPHERICAL TRIANGLE. [SPHERICAL TRIGONOMETRY, &c.]

SPHERICAL TRIGONOMETRY, SPHERICAL TRIANGLE, SPHERICS. We shall confine ourselves in the present article to such a collection of the properties of a spherical triangle as may be useful for reference, referring for demonstration to the treatise on the subject in the 'Library of Useful Knowledge,' and to that on Geometry; adding to the former nothing but a shorter mode of obtaining Napier's Analogies.

By a spherical triangle is meant that portion of the sphere which is cut off by three arcs of great circles, each of which cuts the other two as ABC. It is now usual, however, to consider the spherical triangle as a sort of representative of the solid angle formed at the centre of the sphere by the planes AOB, BOC, COA, as follows:—The arcs AB, BC, CA, are the measures of the angles AOB, BOC, COA, and are used for them: the spherical angles BAC, ACB, CBA are by definition the angles made by the planes BOA and AOC, AOC and COB, COB and BOA. The sperical triangle then has six parts corresponding in name to the six parts of a plane triangle; but a *side* of it means the angle made by two straight *lines* of a solid angle, while an *angle* of it refers to the angle made by two *planes* of the solid angle.



Throughout this article we shall designate the angles by A, B, C, the sides opposite to them by *a*, *b*, *c*; the half sum of the sides by *s*. And by A′, B′, C′, *a*′, *b*′, *c*′, we mean the supplements of A, B, &c., so that A + A′ = 180°, *a* + *a*′ = 180°, &c. No triangle is considered which has either a side or an angle greater than 180°.

Three circles divide the sphere into eight spherical triangles. Of these four are equal and opposite to the other four, with which they agree in every respect but one [SYMMETRICAL] with which we have nothing here to do. Of the four which are distinct, if ABC be one, there are three others thus related to it: the first has for its sides *a*, *b*′, *c*′, and for its angles A, B′, C′,; the second has *a*′, *b*, *c*′, for sides, and A', B, C', for angles; the third has a', b', c for sides, and A', B', C, for angles. Hence every spherical triangle has another, with one side and its opposite angle remaining unchanged, and all the other parts changed into their supplements.

Again, if the three circles be taken which have A, B, and C for their poles, the intersections of these new circles are themselves the poles of AB, BC, and CA; and, of the eight new triangles thus formed, each one has all its *angles* supplemental to the *sides* of its corresponding triangle in the first set, and all its *sides* supplemental to the *angles*. Thus there exists a triangle which has the sides A', B', C', and the angles a', b', c'; which is called the supplemental triangle of that which has a, b, c, for sides, and A, B, C, for angles. Hence if, in any general formula, sides be changed into supplements of angles, and angles into supplements of sides, the result is also a general formula.

Any two sides of a spherical triangle are together greater than the third, and the sum of the three sides is not so great as 360°. Any two angles of a spherical triangle are together less than the third angle increased by 180°, and the sum of the three angles is more than two, and less than six, right angles. And the greater side of a spherical triangle is opposite to the greater angle; and the sum of two sides is greater than, equal to, or less than, 180°, according as the sum of the opposite angles is greater than, equal to, or less than, 180°.

The formulæ for the solution of a spherical right-angled triangle are six in number. Let C be the right angle, and let c be called the *hypothenuse*, as distinguished from a and b, which are still called *sides*. [CIRCULAR PARTS.]

1, 2. The cosine of the hypothenuse is equal to the product of the cosines of the sides, and of the cotangents of the angles:

$$\cos c = \cos a \cos b;\quad \cos c = \cot A \cot B.$$

3. The sine of a *side* is the sine of the hypothenuse into the sine of the *opposite* angle:

$$\sin a = \sin c \sin A;\quad \sin b = \sin c \sin B.$$

4. The tangent of a side is the tangent of the hypothenuse into the cosine of the included angle:

$$\tan a = \tan c \cos B;\quad \tan b = \tan c \cos A.$$

5. The tangent of a side is the tangent of its opposite angle into the side of the other side:

$$\tan a = \tan A \sin b;\quad \tan b = \tan B \sin a.$$

6. The cosine of an angle is the cosine of its opposite side into the side of the other angle:

$$\cos A = \cos a \sin B;\quad \cos B = \cos b \sin A.$$

These formulæ are sufficient for every case. Name any two out of the five a, b, c, A, B (C being a right angle), and in the preceding six formulæ, by repetition ten, will be found those two combined with each of the other three. Thus, having given a side a and its adjacent angle B, we find the other parts from

$$\tan b = \tan B \sin a,\ \tan c = \frac{\tan a}{\cos B},\ \cos A = \cos a \sin B.$$

These formulæ should be committed to memory: the abbreviation, so called, described in CIRCULAR PARTS, is only an expeditious mode of wasting time.

When all the angles are oblique, the principal formulæ are as follows (in most cases we give only one, those for other sides, &c., being easily supplied):—

1. $\dfrac{\sin A}{\sin a} = \dfrac{\sin B}{\sin b} = \dfrac{\sin C}{\sin c}$; or the sines of sides are to one another as the sines of their opposite angles.

2. $\cos c = \cos a \cos b + \sin a \sin b \cos C$.

3. $$\cos\frac{C}{2} = \sqrt{\frac{\sin s\ \sin(s-c)}{\sin a\ \sin b}}$$

$$\sin\frac{C}{2} = \sqrt{\frac{\sin(s-a)\ \sin(s-b)}{\sin a\ \sin b}}.$$

4. $$\tan\frac{C}{2} = \sqrt{\frac{\sin(s-a)\sin(s-b)}{\sin s\ \sin(s-c)}} = \frac{M}{\sin(s-c)};$$

where $M = \sqrt{(\sin(s-a)\ \sin(s-b)\ \sin(s-c) \div \sin s)}$.

5. $$\tan\frac{A+B}{2} = \cot\frac{C}{2}\,\frac{\cos\frac{1}{2}(a-b)}{\cos\frac{1}{2}(a+b)}$$

$$\tan\frac{A-B}{2} = \cot\frac{C}{2}\,\frac{\sin\frac{1}{2}(a-b)}{\sin\frac{1}{2}(a+b)}.$$

6. $\cot a \sin c = \cos c \cos B + \sin B \cot A$.

7. $\tan\theta = \sin\frac{1}{2}C\sqrt{\sin a\ \sin b} \div \sin\frac{1}{2}(a-b)$,
gives $\sin\frac{1}{2}c = \sin\frac{1}{2}(a-b) \div \cos\theta$.

8. $\sin\theta = \sin\frac{1}{2}C\sqrt{\sin a\ \sin b} \div \cos\frac{1}{2}(a-b)$,
gives $\cos\frac{1}{2}c = \cos\frac{1}{2}(a-b)\cos\theta$.

The formulæ (5) which are called Napier's Analogies, may be demonstrated more easily than in the usual way, as follows. First—

$$\tan(\tfrac{1}{2}A \pm \tfrac{1}{2}B)\,.\tan\tfrac{1}{2}C = \frac{\tan\frac{1}{2}A\tan\frac{1}{2}C \pm \tan\frac{1}{2}B\tan\frac{1}{2}C}{1 \mp \tan\frac{1}{2}A\tan\frac{1}{2}B}$$

$$\text{from (4) } \tan\tfrac{1}{2}A\tan\tfrac{1}{2}B = \frac{\sin(s-c)}{\sin s},\ \&c.$$

$$\tan(\tfrac{1}{2}A \pm \tan\tfrac{1}{2}B)\,.\tan\tfrac{1}{2}C = \frac{\sin(s-b) \pm \sin(s-a)}{\sin s \mp \sin(s-c)}.$$

[TRIGONOMETRY.] $\tan(\tfrac{1}{2}A + \tfrac{1}{2}B)\,.\tan\tfrac{1}{2}C = \dfrac{2\sin\frac{1}{2}c\ \cos\frac{1}{2}(a-b)}{2\sin\frac{1}{2}c\ \cos\frac{1}{2}(a+b)}$

since $2s - a - b = c$. Hence the first of (5) easily follows, and the second in a similar manner.

The formula (6) is not easily remembered, except by the following:—Write the sides in any successive pairs, as ab, bc, ca, or ac, cb, ba: change the last three into the corresponding angles giving ab, bc, CA, or ac, cB, BA; remembering the formula cos ÷ sin = cot make the middle terms cosines, those on the right and left sines, and those on the extreme right and left cotangents. We have then—

$$\cot a \sin b = \cos b \cos C + \sin C \cot A,$$

which is a case of the formula in question.

We now proceed to the different cases of triangles, observing that these may be taken in pairs, owing to the property of the supplemental triangle. Thus, suppose it granted that we can solve the case of finding the three angles when the sides are given, it follows that we can solve that of finding the three sides from the three angles. For, if A, B, and C be given, find the *angles* of the triangle whose sides are A', B', and C'. If a', b', and c' be these angles, then a, b, c are the sides of the original triangle. Nor is it worth while to separate the several cases, since it generally happens that out of each pair one is of much more frequent occurrence than the other.

Case 1.—Given the three sides, to find the three angles. If one angle only be wanted, one of the formulæ (3) answers as well as anything. If all three angles be wanted, the shortest way is to calculate M from

$$M = \sqrt{\{\sin(s-a)\ \ \sin(s-b)\ \ \sin(s-c) \div \sin s\}}$$

and then the angles from

$$\tan\tfrac{1}{2}A = \frac{M}{\sin(s-a)},\ \tan\tfrac{1}{2}B = \frac{M}{\sin(s-b)},\ \tan\tfrac{1}{2}C = \frac{M}{\sin(s-c)}$$

Supplement.—Given the three angles, to find the three sides. Make the supplements of the given angles sides, calculate the three angles, and the supplements of the last three angles will be the sides required.

Case 2.—Given two sides (a and b), and the included angle C, to find the remaining parts. If all the parts be wanted, calculate $\frac{1}{2}(A+B)$ and $\frac{1}{2}(A-B)$ from (5), and then find A and B by addition and subtraction: lastly, find c from one of—

$$\sin c = \sin b\,\frac{\sin C}{\sin B},\ \sin c = \sin a\,\frac{\sin C}{\sin A};$$

or from both, which will be a verification. But if the remaining side only be wanted, use the formula (7) or (8), which gives this third side at once, by means of the subsidiary angle θ. Or from the extremity of the shorter side given (say a), let fall a perpendicular arc z on b, dividing b into x and y. Then—

$$\tan x = \tan a \cos C,\quad \sin z = \sin a \sin C$$

$$y = b - x,\quad \cos c = \cos z \cos y.$$

Supplement.—Given a side (c) and the two adjacent angles (A and B); required the remaining parts. Make A' and B' the sides of a triangle, and c' the included angle; find C' the remaining side, and a' and b' the remaining angles. Then C is the remaining angle of the original triangle, and a and b are the remaining sides. To find the remaining sides alone, the following formula may be used:

$$\tan\frac{a+b}{2} = \tan\frac{c}{2}\cdot\frac{\cos\frac{1}{2}(A-B)}{\cos\frac{1}{2}(A+B)}$$

$$\tan\frac{a-b}{2} = \tan\frac{c}{2}\cdot\frac{\sin\frac{1}{2}(A-B)}{\sin\frac{1}{2}(A+B)}$$

Case 3.—Given two sides (a and b) first both less than a right angle, and an angle opposite to one of them (A); required the remaining parts. This case may afford no solution at all, or may give two solutions; it is therefore sometimes called the ambiguous case. The formula (6) may be used by the usual introduction of a subsidiary angle; but we should recommend a person who is not well practised in the subject to prefer the following simple method:—From the extremity of b which is *not* adjacent to the given angle, drop a perpendicular z on the side c, and let x be the segment adjacent to A. Let $a\hat{}z$ and $b\hat{}z$ be the angles made by a and b with z. And first calculate $\sin b \sin A$; if this be greater than unity, the triangle does not exist; if it be equal to unity, the triangle is right angled at B, and may be treated as a right-angled triangle. But if $\sin b \sin A$ be less than unity, find z from $\sin z = \sin b \sin A$, and x and B from

$$\tan x = \tan b \cos A, \sin B = \sin A \frac{\sin b}{\sin a}.$$

There are two values of B, supplements of each other, both of which are possible answers. Let B be the one which is less than a right angle, and B′ that which is greater.

First, when A is acute and a less than b. Calculate y from $\cos y = \cos a \div \cos z$, and $b^{\wedge}z$ and $a^{\wedge}z$ from

$$\cot b^{\wedge}z = \cos b \tan A, \quad \cos a^{\wedge}z = \frac{\tan z}{\tan a}.$$

There are two triangles which satisfy the data; in the first, $c = x - y$, B′ is the angle opposite to b, and $C = b^{\wedge}z - a^{\wedge}z$; in the second, $c = x + y$, B is the angle opposite to b and $C = b^{\wedge}z + a^{\wedge}z$.

Secondly, when A is acute and a equal to or greater than b. Calculate exactly as in the last case, but there is only one triangle which satisfies the data, namely, the second of the preceding.

Thirdly, when A is obtuse, in which case there is no triangle, unless a be greater than b. Calculate (using A as more convenient)

$$\sin z = \sin b \sin A', \tan x = \tan b \cos A, \sin B = \sin A' \frac{\sin b}{\sin a}$$

Use the value of B which is less than a right angle; calculate $b^{\wedge}z$ and $a^{\wedge}z$ from

$$\cot b^{\wedge}z = \cos b \tan A', \cos a^{\wedge}z = \frac{\tan z}{\tan a}.$$

Then $c = y - x$, and $C = a^{\wedge}z - b^{\wedge}z$.

In the case in which one or both of the sides are greater than a right angle, which rarely, if ever, occurs, it is best to have recourse to one of the adjacent triangles described at the beginning of this article, and to use it in the same manner as the supplementary triangle has been used. It is not however necessary to dwell on this point.

Supplement.—Given two angles (A and B) and a side opposite to one of them (a); required the remaining parts. Let A′ and B′ be the sides of a triangle, and a' the angle opposite to A′. Find C′ the remaining side, and b' and c' the remaining angles; then C is the remaining angle of the original triangle, and b and c the remaining sides.

All the cases would need some subdivision to adapt them to calculation, if it were really often required to solve triangles with very large sides and angles. But in application it generally happens that the reasoning of the previous part of the process is so conducted as to throw the calculation entirely upon triangles which have at least two sides and two angles severally less than a right angle. Divide a great circle into three parts, and we have the extreme limit of a spherical triangle: the sum of its sides being 360°, and the sum of its angles six right angles. But a triangle which should be very near to this limit would be best used in reasoning, and solved in practice, by means of one of the other seven triangles into which its circles divide the sphere. And if one of the sides should be greater than two right angles, the remainder of the hemisphere would be the triangle on which calculation is employed. And it is to be understood that all the formulæ are demonstrated only for the case in which every side is less than two right angles. At the same time we should recommend the beginner to procure a small sphere, and to habituate himself to the appearance of all species of triangles.

The area of a spherical triangle is singularly connected with the sum of its angles, on which alone it depends, the sphere being given. Let any two triangles, however differently formed, have the sum of their angles the same, and they must have the same area. If the angles be measured in theoretical units [ANGLE], the formula is as follows: r being the radius,

$$\text{Area} = r^2 (A + B + C - \pi),$$

which gives the number of square units in the area, the radius being expressed in corresponding linear units. But if the angles be measured in degrees and fractions of a degree, the formula is

$$\text{Area} = \cdot 01745329252\, r^2 (A + B + C - 180).$$

The angle A + B + C − 180° is called the *spherical excess*, and it may be found at once from the sides by the formula

$$\tan^2 \frac{\text{sph. ex.}}{2} = \tan \frac{s}{2} \tan \frac{s-a}{2} \tan \frac{s-b}{2} \tan \frac{s-c}{2};$$

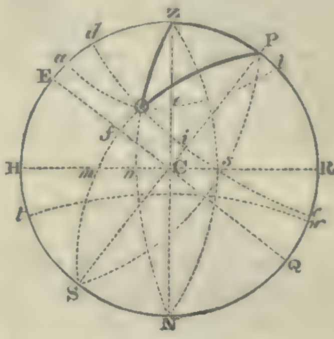
so that the area of a triangle is easily found from its sides. If a spherical triangle were flattened into a plane one, without any alteration of the lengths of its sides, it is obvious that the sum of the angles would undergo a diminution, being reduced to 180°. The angles would not diminish equally; but, if the sphericity of the original triangle were small, or if it occupied only a small part of the sphere, the diminutions which the several angles would undergo in the process of being flattened would be so nearly equal, that it would be useless, for any practical purpose, to consider them as unequal. For a triangle of small sphericity, then, it may be assumed that in being flattened, each of its angles loses one-third of the spherical excess. This proposition is one of considerable use in the measurement of a degree of the meridian.

SPHEROGRAPH, an instrument invented in 1856, for facilitating the practical use of spherics in navigation, &c., being a contrivance for constructing, without dividers or scales, any possible spheric triangle, and reading off the measures of the parts required; thus in most cases saving much time and labour. The degree of accuracy of the instrument is limited only by its size, but it has been found by navigators that circles of 5-inch radius will work any question which arises at sea, sufficiently near for the practical purposes of the navigator.

The description of the instrument will be better understood by giving some general preparatory hints as to the names of the ordinary lines of the sphere.

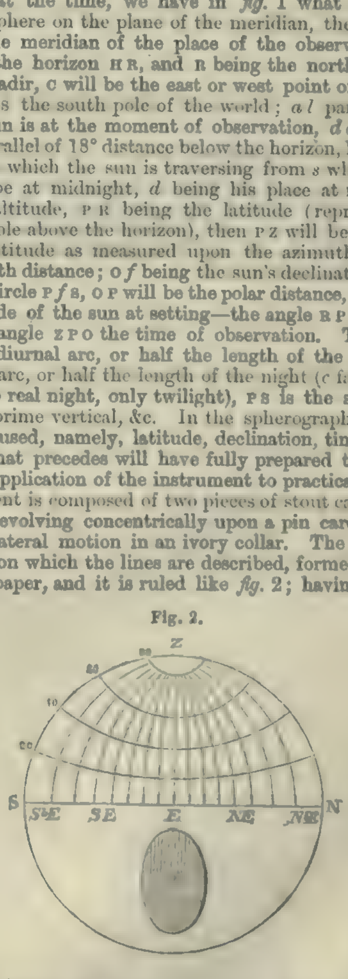
In the following figure, No. 1, the observer is supposed to be at the centre C of a hollow transparent sphere, on which the usual lines are drawn as upon a terrestrial globe. He would see the sun as at O upon the globe's surface amongst these lines. Rejecting all superfluous circles, &c., and confining our description to such parts as affect the sun's position at the time, we have in *fig.* 1 what is called a projection of the sphere on the plane of the meridian, the primitive circle representing the meridian of the place of the observer, H being the south part of the horizon H R, and R being the north, Z will be the zenith, N the nadir, C will be the east or west point of the horizon, P the north pole, S the south pole of the world; *a l* parallel of altitude in which the sun is at the moment of observation, *d c* the sun's declination, *t w* a parallel of 18° distance below the horizon, limiting twilight to the period at which the sun is traversing from *s* where he sets, to *c* where he will be at midnight, *d* being his place at noon; H *d* being the meridian altitude, P R being the latitude (represented by the height of the pole above the horizon), then P Z will be the co-latitude, O *n* the sun's altitude as measured upon the azimuth circle Z *n*; O Z will be the zenith distance; O *f* being the sun's declination as measured upon the hour circle P *f* S, O P will be the polar distance, E Q the equator, Z *s* the amplitude of the sun at setting—the angle R P *s* being the time of sun-set, the angle Z P O the time of observation. The small circle *d s* is the semi-diurnal arc, or half the length of the day, and *s c* the semi-nocturnal arc, or half the length of the night (*c* falling within R *w* there will be no real night, only twilight), P S is the six o'clock hour-circle, Z N the prime vertical, &c. In the spherograph only five terms are principally used, namely, latitude, declination, time, azimuth, and altitude, and what precedes will have fully prepared the mind of the reader for the application of the instrument to practical purposes.

Fig. 1.



The instrument is composed of two pieces of stout card-board, nicely attached, and revolving concentrically upon a pin carefully turned to work without lateral motion in an ivory collar. The upper card has the ruled part, on which the lines are described, formed of stout transparent tracing paper, and it is ruled like *fig.* 2; having only azimuths and parallels of altitude (it has an oval space cut so as to enable the observer to put pencil marks on the under sphere), while the unde

Fig. 2.



one (*fig.* 3) has hour circles and parallels of declination: for of the three parts always given in every spheric triangle, two will fall on either one of the cards, and their intersection is made to touch the third datum as found in the other. We will suppose, in illustration, that we have given the sun's altitude 48°, the declination 10° N., and the apparent time 11 h. A.M., to find the latitude. If we discard all the lines that are not necessary to the working of this question, we shall, in *fig.* 4, have a view of the spheric triangle under consideration, which, had it been merely projected on a plane, must have been worked by computation, thus: in the spheric triangle Z O P we have O Z = zenith distance, O P the polar distance, and Z P O the hour angle, to find Z P the co-latitude, and thence P R the latitude. By the spherograph this question of latitude is answered (simultaneously with numerous other results not asked for in this) by *simply turning the upper sphere on the under*, until the place where the time and declination on the under sphere coincide with some part of the parallel of given altitude on the upper. The instrument is thus said to be set, and the measures of altitude, azimuth, time of sun setting, rising, &c., are at once read off: while without the spherograph the latitude alone would require the following work (and one illustration of its saving of time and labour will suffice):—

Fig. 3.

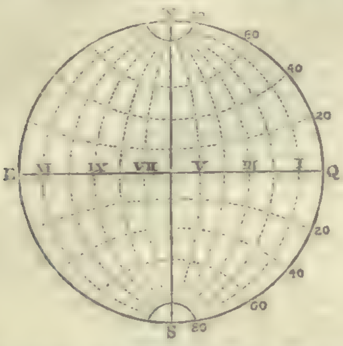
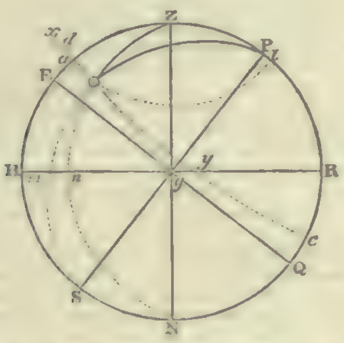


Fig. 4.



After letting fall a perpendicular in *fig.* 4 from the centre *g* through *o* to *x* [SPHERICAL TRIGONOMETRY], O *d* P will be a right angle, then by circular parts in triangle P Z O find angle Z, thus,—

As sine zenith distance O Z, 42° . co. ar. 0·174489
Is to sine hour-angle P, 15° . . . 9·412996
So is sine polar distance O P, 80° . . . 9·993351

To sine angle Z, 180°—22° 23′ = 157° 37′ = 9·580836

In △ *d* P O find *d* P.

As cotang. polar distance, 80° . co. ar. 0·753681
Is to cosine hour-angle, 15° . . . 9·984944
So is radius . . . . 10·

To tangent side *d* P, 79° 39′ . . = 10·738625 = 79° 39′

In △ *d* Z O find *d* Z.

As cotang. zenith distance, 42° . co. ar. 9·954437
Is to cosine 180°—157° 37′ = 22° 23′ . . 9·965981
So is radius . . . . . . 10·

To tangent of *d* Z, 39° 47′ . . = 9·920418 = 39° 47′

Co-latitude = 39 52
90

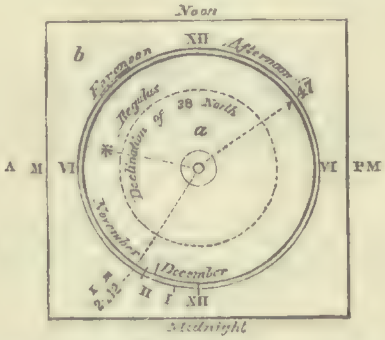
Latitude = 50 8

The spherograph is of different forms, to suit special purposes. Figures 2 and 3 combined, 2 being the upper sphere, represent its general form for latitude, time, azimuth, altitudes, and declination; and it has introduced a new mode of navigating ships in places subject to fogs and haze: for instance, the Montreal traders use it on the Banks of Newfoundland, by substituting azimuth for altitude, in the three things given, when the horizon is entirely invisible, the sun being in sight. It also dispenses with double altitudes, inasmuch as latitude can be as well determined by it from a single observation as from two, rendering all *elapsed* time uncalled for. But it is not our purpose to describe these methods in detail. It seems, however, that a means of so readily finding the position of a fast-sailing steamer when approaching the land is important.

It is well known that one common source of error in working sea observations taken at night, is the liability to mistake the name of a star. This instrument provides a very handy method of correctly finding the name of any star of the first magnitude, even when others around it are obscured. The inventor of the spherograph, Mr. Stephen Martin Saxby, R.N., had noticed that no two stars of the first magnitude had equal declinations in either hemisphere, or were within two or three degrees of each other in that respect. By having a list of such stars and their declinations on the face of the instrument, the name of any star of first magnitude is easily obtained in the following manner:—Using merely approximate data, such as latitude, altitude, and azimuth, we apply them thus: suppose a star has an altitude of about 10°, its true bearing [BEARING] being N.E., the estimated latitude of the place being 43° N.; setting the instrument to the latitude, the intersection of these three elements would on the line of declination be 38¼° N. Reference to the list of stars on the instrument would at once show that this declination could only apply to the star *α* Lyræ.

In working a night observation, the finding of the right ascension is rendered in the spherograph peculiarly simple, and is divested of all liability to error from the occasional fault of adding instead of subtracting, &c. A form of spherograph is prepared for this. (See *fig.* 5.)

Fig. 5.



The inner circle *a* revolves upon a centre-pin connecting it with *b* the under part. On this circle the principal stars are delineated according to their right ascensions, which are measured on its circumference, and their declinations as measured upon a radius. To avoid confusion, we omit, in the above figure, all but Regulus. Suppose at $2^h\ 12^m$ a.m., on the 5th of November, a navigator was desirous of using Regulus as a means of obtaining his latitude, &c. On turning the circle till the date 5th November, marked on it, coincided with $2^h\ 12^m$ marked upon the outer part *b*, he would find that a line through Regulus would cut a point on the part *b* at the distance of $5^h\ 5^m$ from the part of the circle marked Noon. This, then, would be the star's distance from the meridian, and would be used in the common form of spherograph made up of *figs.* 2 and 3, as if it were time by the sun. Thus night observations are rendered as easy as those taken by day.

There is another peculiarity of the instrument. Heavy southerly gales in the English Channel, when they clear up, generally do so by the clouds breaking in the N.W. to N., so that the polar star is generally about the first star visible. At such times, the mariner eagerly attempts to obtain his latitude, and the form of spherograph *fig.* 5, is a very great convenience. Suppose he have obtained an altitude of the polar star = 50° 5′ at $2^h\ 12^m$ a.m. of 5th November; having set the date to the hour as before, the polar index engraved on the circle will point to some one of the figures engraved round the circle on the part *b*; in this instance it would be to 47′ subtractive: then 50° 5′ − 47′ = 49° 18′, the true latitude, to the nearest mile. The readiness of the method admits of increased number of observations; and, consequently, by using the *means* of such observations, the present prevailing error from the indistinctness of the horizon is greatly diminished.

We shall only notice one other use of the spherograph as greatly curtailing labour of computation—namely, in lunar observations. The lines on *fig.* 6 are thus obtained (and here, again, a knowledge of the principles on which the lines are constructed is not at all necessary to the successful use of it):—

Taking advantage of the circumstance that refraction varies nearly as the tangent of the zenith distance, and as tan. 45° = radius, we take, in the projection for refraction, the radius as the refraction at 45°

zenith distance. It fortunately happens that 58″·4, the number of seconds in the refraction at 45°, nearly corresponds with the number of minutes in the mean horizontal parallax. The same diagram does therefore for both parallax and refraction, substituting seconds for minutes.

In the following figure (6), therefore, CA, or CM, or CD = moon's horizontal parallax; MCS = apparent distance between the sun and moon, M being the moon's place in the figure and S the sun's; or the arc MS = apparent distance. MZ = the moon's zenith distance, or, as every part of the small parallel of altitude, FE, is equally distant from M, CH on the line of sines will equal the moon's altitude.

And again, ST will be the sun's zenith distance, and therefore CK on the line of sines will equal the sun's altitude, AD being the moon's horizon and hr the sun's; HE will be the moon's parallax in altitude;

Fig. 6.

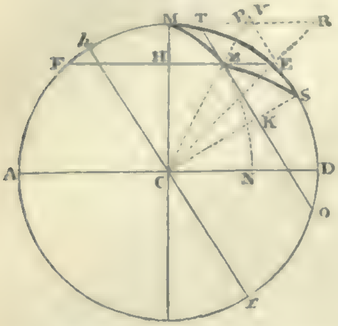
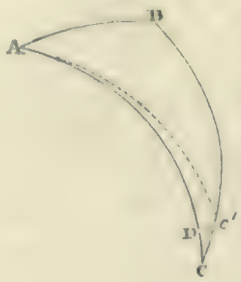


Fig. 7.



and HE : CD :: cos. ED : radius, or the moon's parallax in altitude = $\frac{\text{hor. pax.} \times \text{cos. moon's alt.}}{\text{radius}}$.

And in the orthographic projection of the lunar triangle MSZ on a scale where radius is = moon's hor. parallax, or CD, the angle M is the angle at the moon corresponding with the angle C in the usual lunar construction, as in *fig.* 7; and CN (the distance of the orthographic great circle MN passing through Z, where the sun's and moon's horizons coincide) is the cosine of this compared with radius CD. But CD : CN :: HE : HZ; or HZ is the correction for parallax = $\frac{CN \times HE}{\text{radius}}$, and is measured from HZ by the scale of chords from the nature of the projection. (In *fig.* 7, CC′ : CD :: rad. : cos. C, CC′ being the moon's parallax in altitude, and CD the correction for parallax.) In *fig.* 6, moreover, MR = tangent of moon's zenith distance, in seconds for alt. 45°; MP, correction for moon's refraction in seconds; SV = correction for sun's refraction in seconds. Such being the principles on which this part of the spherograph is constructed, the following is the form of each of the parts:—The under sphere has its line MC crossed by parallel circles drawn to the scale of sines, or on the orthographic projection; these are again crossed by lines parallel to MC, CD being divided into 60 parts by the line of chords (being very nearly 58″·4 of refraction at 45°, as above).

The practical use of the spherograph in correcting a lunar distance may be thus briefly illustrated: suppose, for example, the apparent distance given = 72°, the moon's altitude = 26°, the sun's altitude = 32°, and the reduced horizontal parallax = 59′. Moving the circles concentrically until M and S are moved 72° apart in *fig.* 6; = the apparent distance, where the two horizons AD and OT cut each other, will give a point which, counting the vertical lines from MC, each will be one minute of correction (as read upon CD); this correction, multiplied by a number taken from a small table printed on the back of the instrument, gives at once a correction for the distance, thus:—

The number read on CD = ...	24′
The tabular multiplier = . . .	·952
	3808
	1904
	22·818 = 22′ 51″
The apparent distance	72° 0′ 0″
Sum of corrections (subtractive) . . .	22 51
True distance by spherograph . . .	71 37 9
Elaborate logarithm calculation gives . .	71 37 8
	1″ error.

When the intersection of the horizons falls on the right of MC, the correction is subtractive; when to the left, it is additive. The spherograph is especially useful to check observations when worked out by logarithms, and imparts confidence to a navigator. A little work published by Longman and Co., called 'Calculation and Projection of the Sphere,' plainly illustrates the general mode of spheric construction.

SPHEROID, a name given to the class of surfaces which are formed by the revolution of an ellipse about either its longest or shortest diameter. When the longer diameter is the axis, the spheroid is called *prolate;* when the shorter, *oblate.* The earth is an oblate spheroid, or very near indeed to such a figure: hence the oblate spheroid is of much more importance than the prolate one. The general properties of the spheroid are either those which belong to it as particular cases of SURFACES OF THE SECOND DEGREE, or those which are useful in geodesy, and which belong more to the generating ellipse than to the surface.

SPHEROIDAL CONDITION OF LIQUIDS. [EBULLITION.]

SPHINX. The name applied in glyptic art to the combinations of lions' bodies with other forms; that with a human head being called androsphinx, with a ram's criosphinx, and with a hawk's hieracosphinx. They appear to have been derived from Egypt, where they were sculptured as symbolical representations of kings and queens, and they expressed in the hieroglyphic texts the idea of *neb* lord, or *akar* victory, or the sun on the horizon. In Egyptian art they are represented couchant, with a human head, the portrait of the monarch they personify; and recent excavations at Tanis have shown that they are as old as the 17th dynasty of Shepherds, the king Apepa or Aphophis being thus represented. In Egyptian art they are rarely winged, the only example being the sphinx of the queen Mutnemt at Turin; Thothmes III. and other monarchs, even the young Alexander and Ptolemies are personified as sphinxes, and there are some small sphinxes in European collections, as one in the Louvre, at Paris, of Rameses II., 23 feet long, of a block of red syenite, and a black granite sphinx of Amenophis III. at St. Petersburg; but the largest is that at Gizeh, of 143 feet long and 62 feet high, cut out of the solid rock, and lying about 1960 feet east of the second pyramid. This was called Har-ma-khu, or Harmakhis, "Horus on the Horizon," and adored as a god by Thothmes IV. and Rameses II. It was approached by a staircase and surrounded by a kind of peribolos, having a temple of alabaster and granite attached to it, in which was a well filled with Nile water, into which had been thrown seven statues of green and yellow breccia of the monarch Shafra, or Kephren, the builder of the second pyramid. Winged sphinxes are often seen in Assyrian and Babylonian art, and seem to represent deities or monarchs under this form.

The few remains of Phœnician art show that this people had adopted the form of the sphinx, probably from Egyptian sources, and the Etruscans seem to have derived the same from their oriental connection, their early works of art being often decorated with representations of this monster. The same may be also said of the Greeks and other cognate races, winged sphinxes being a common type in Greece, Lycia, and other localities. At the earliest period of art sphinxes have recurved wings, but on some later monuments they are unwinged. They have the face and breasts of a beautiful but cruel female, the body of a lioness, and sometimes the tail of a dragon. According to the earliest myths, the Sphinx was the daughter of Typhon and Echidna, Orthus or Typhon and Chimæra, and being sent by Juno to punish the Thebans, proposed a fatal riddle or enigma which was solved by Œdipus, and the Sphinx destroyed. Sphinxes are also found in India as the ornaments of temples.

(Mariette, Aug., *Revue Archéologique*, 1860, p. 18-20, 1861, p. 20; Birch, *Mus. Class. Antiq. II.* p. 27; Vyse, *Pyramids, III.* p. 107; Letronne, *Inscr. Grec.* ii. 460-461; Champollion, *Lett. à M. le Duc de Blacas*, 8vo. Paris, 1824; Layard, *Nineveh;* Winckelmann, *Werke;* Voss, *Myth. Br.* ii. p. 22; Müller, *Arch. d. Kunst*, p. 700.)

SPIGELIA MARYLANDICA, Carolina pink, perennial worm-grass, or worm-seed; a perennial herbaceous plant, native of the southern states of the American Union. It is from six inches to two feet high, leaves opposite, sessile, ovate, and acuminate. The root has a short caudex, from which issue numerous fibres; all which parts are of a yellowish colour when first dug up, but become black on drying. It is collected by the Indians, and sold to the white traders, who pack it in casks, or make it up into bales, weighing from three hundred to three hundred and fifty pounds. The odour of the fresh plant is disagreeable, the taste sweetish, slightly bitter, and nauseous. The leaves are less potent than the root, which part consists of woody fibre 82, a peculiar principle like tannin 10; bitter acrid extractive 4; and an acrid resin; also a fixed and a volatile oil. Both the resin and extractive have emetic properties. Spigelia has slight narcotic powers, and in large doses causes vomiting and purging. In America the fresh plant has decided anthelmintic virtues, but it is only useful against the *Ascaris lumbricoides*, or large round worm. In Europe it is little used, having lost much of its power by long keeping. Dr. Barton recommends it as a cure for the infantile remittent fever, which often terminates in hydrocephalus, or water in the head. In such a case it acts beneficially by removing the worms, the irritation of which, when propagated to the brain, gives rise to the more serious disease. But the expulsion of the worms by any other means, and the exhibition of any tonic and astringent, like the tannin of the Spigelia, will prevent their recurrence. [ANTHELMINTICS.]

Spigelia is given in powder, or as an infusion or decoction. It is usually combined with senna or some other purgative, but it is better to give it alone, and follow its administration by a dose of calomel and jalap.

The *Spigelia Anthelmia*, a native of Brazil, which is a much more potent plant, is sometimes mistaken and given for the other. It contains an alkaloid called spigelina, which is volatile, somewhat like nicotina, the effects of which it also resembles, causing formidable narcotic symptoms, to which lemon-juice, sugar, or carbonate of potash is said to be an antidote.

SPINA BI'FIDA, or cleft-spine, is a disease commencing in fœtal life, and which consists in an imperfection of the posterior part of the spinal canal. It is almost always accompanied by an excessive secretion of spinal fluid, and in these cases it may be regarded as a disease of the same kind affecting the spinal canal as that which, existing in the skull, constitutes hydrocephalus. The two are indeed not unfrequently coincident; and spina bifida is sometimes called hydrorachis.

The arch of each vertebra [SKELETON, in NAT. HIST. DIV.] is developed and ossified in two pieces which meet behind in the middle line at the base of the spinous process. This is also developed in two lateral portions which subsequently unite together and with the arch, so as to form the one piece of bone which we find in the adult closing in the back of the spinal canal. This development and union of the arches of the vertebræ goes on during an early period of fœtal life, while the spinal column is growing rapidly, and the fluid of the spinal canal and arachnoid sac is being constantly secreted. If this fluid be secreted in an unnaturally large quantity before any or a part of the arches of the vertebræ are completely ossified, it may exert such pressure upon them as to separate their component parts, and produce a permanent aperture in the back of the spinal canal, through which a sac containing the excess of fluid will protrude. Or if the development and ossification of any or all of the arches take place more slowly than it should, then a secretion of not more than the ordinary quantity of fluid may suffice to keep them permanently open. A cleft spine will thus be produced without the watery tumour; but the openness of the spine will generally in cases of this kind lead to the secretion of an unnatural quantity of the spinal fluid; for it seems a general law that, other things being equal, the quantity of fluid secreted in each part is inversely proportionate to the resistance offered by the walls of the cavity into which it is poured.

Spina bifida is almost always characterised by a tumour situated over the defective vertebræ, globular, elastic, and fluctuating, often attached by a narrowed base, and varying in size according to the extent of the fissure in the spinal canal. It is usually covered by healthy skin, and consists of the dura mater, and one or more of the other membranes of the spinal cord, protruded in a sac through the space between the separated arches, and filled by a clear serous fluid. On pressing such a tumour the patient may become insensible, or be convulsed; for the fluid within it communicating with that within or around the brain and spinal chord, the pressure made upon it is felt with equal force by the whole of those organs. The parts of the body below the tumour are often paralytic, not from the pressure of the fluid, for that is equally diffused, but from disease of the cord coincident with that of the arches.

Spina bifida is most common in the lumbar and sacral regions, in which the vertebral arches are latest completed: it is most rare in the neck, and is there also most dangerous, because of the great number of nerves which, by the coincident disease of the spinal cord, may be paralysed. It does not commonly interfere with the general health: but by the friction to which, when the tumours are large, the skin is subjected, and by the distension produced by the increasing secretion of fluid, the sac is liable to inflame and ulcerate, till, exposing the spinal cord, or its membranes, death is produced by their inflammation; or, the quantity of fluid secreted may be so great as to produce death by its pressure on the cord and brain, in a manner similar to that in which hydrocephalus often terminates.

In one of these modes, spina bifida, when accompanied by excessive secretion, almost always terminates fatally, though patients may survive with it for ten or even twenty years. Life may generally be prolonged by maintaining a gentle even pressure upon the tumour, so as to supply the necessary resistance to the effusion of more fluid. In a few cases a repeated evacuation of the fluid, and then firm pressure upon the sac, has been found successful; and lately, M. Tavignot has related some cases which he cured by slicing off the tumour, and instantly bringing together the edges of the mouth of the sac, and so holding them till they had united and formed a firm cicatrix.

That just described is by far the most common form of spina bifida; others more rare are those in which not the arches only, but the bodies of the vertebræ also are cleft, the two lateral portions in which each is developed being kept apart, so that a portion of the spinal canal is open in front towards the cavity of the abdomen. Some differences of character also depend on the seat of the fluid secreted: it is generally in the sac of the arachnoid, but sometimes is in the tissue of the pia mater, or in both it and the sac, or, yet more rarely, in the central canal of the spinal cord.

SPINA VENTO'SA is a term now obsolete, which was applied by old surgeons to abscesses in bone, accompanied with excessive swelling, and then to nearly all the diseases indiscriminately in which either bones or joints become enlarged.

SPINACH. One of the species of this genus, the *S. oleracea*, the common spinach, is well known on account of its use in the kitchen. It has an herbaceous stem one or two feet high, branched, and hollow; arrow-shaped leaves; male flowers in long spikes, abounding with pollen; female flowers on another plant, axillary, herbaceous, and small. The fruit is a small round nut, which is sometimes very prickly.

There are two principal varieties cultivated in gardens, the prickly-fruited, with triangular, oblong, or sagittate leaves, and the smooth-fruited, with round or blunt leaves. The former is considered the hardiest, and is therefore employed for winter culture; the latter is used for summer crops. Of these varieties there are several sub-varieties, varying in the size, thickness, and shape of their leaves.

For the winter crop the seed is sown at the beginning of August. A light, dry, rich soil should be preferred, and, if possible, in a sheltered situation. When the plants have put forth two pair of leaves, the ground should be hoed and the plants thinned. By October or November the outer leaves of the spinach are fit for use. In February, when fine weather occurs, the plants should be again attended to, cleaned, and thinned out, and in this way it may be made productive till April or May, by which time the summer sort will be ready. The first sowing of the round-leaved spinach or smooth-fruited should take place at the end of January in some sheltered border. This crop should be successively thinned out till the plants are eight or ten inches apart. Successive sowings may be made, in order to ensure a constant supply in February, March, and April, and, if desirable, these sowings may take place between rows of cabbages, &c.

Spinach is often sown in narrow drills, which is rather more troublesome at first, but this is made up for by the facility with which clearing, thinning, and gathering are afterwards accomplished.

For preserving seed, those plants which are of the most stocky growth should be selected. The winter crops run up soonest, but seed may be obtained from spring crops in July and August. The new seed is the best for sowing, although it will keep very well for a year. When the plants are saved for seed, the male plants, which are easily distinguished by their flowers, may after fertilisation be drawn and thrown away.

Spinach is sometimes grown by the farmer for the purpose of obtaining a crop of seed for the uses of the gardener. In the selection of land for this purpose, care should be taken that it is finely prepared by ploughing and harrowing in the early spring, and some well-rotted dung should be ploughed in where the soil is not of the best quality. When the spinach has blossomed, the male plants should be drawn out, which serve at this time as excellent food for pigs, and might be given to other animals with advantage. There is much uncertainty about this kind of crop; sometimes, however, it turns out very advantageous.

SPINAL IRRITATION. This term has been applied to those functional disorders of the spinal cord and its nerves, which do not readily fall under the definitions of diseases of the same organs having more precise symptoms. Under the heads TETANUS, CHOREA, HYSTERIA, NEURALGIA, HYDROPHOBIA, and PARALYSIS, will be found descriptions of definite derangements of the spinal cord and its nerves. But there is a general state of the nervous system in which some of the symptoms of one or all of these diseases may occasionally be present, and in which there is very commonly present, pain in the spinal column induced or increased by pressure or percussion. To this state the term "spinal irritation" has been applied. What the precise condition of the nervous system is in this disease it is impossible to say, but the general theory of its nature is that the spinal cord at some one or more points is congested, and that this congestion acts upon the sensitive or motor nerves proceeding from this part of the cord, and gives rise to the pains, spasms, and other anomalous symptoms complained of by the patient. This condition is not unfrequently referred to hysteria, but as it may come on in the male as well as the female, there is evidently an impropriety in the use of this term.

It would be quite impossible to describe here all the nervous symptoms that may be referred to spinal irritation. Wherever nerves of motion and sensation are distributed they may become disordered, and thus there is no organ or part of the body that may not be the seat of excessive pain or paralysis of sensation, of spasmodic or convulsive action, and of a paralysis of motion. Such symptoms when they are not fixed, and are connected with pain on pressure of the spinal cord, are said to depend on spinal irritation. Whether these symptoms depend on a morbid condition of the spinal cord, or of the muscular or nervous tissue, or of the blood, are still questions admitting of discussion.

The treatment of these cases has been directed very much by the theory held with regard to the cause of the nervous symptoms. Those who advocate the theory of congestion of certain portions of the cord, recommend the employment of counter-irritants over the tender part of the spine, whilst those who believe that they arise from an under nutrition of the nervous and muscular tissues, recommend a treatment addressed to the restoration of the nutritionary powers of the system. Those who think the blood is the source of the disorder, likewise adopt the same general principles of treatment.

Whatever may be the theoretical views held with regard to the nature of the symptoms, known under the name of spinal irritation, there seems to be a general agreement that they come on in asthenic states of the system, and that antiphlogistic measures must not be had recourse to without great caution.

Relief from pressing occupations, a nutritious diet, change of air, cold bathing, the preparations of iron and quinine, are the great means that must be looked to for the cure of the disordered states of the nervous system. When the painful symptoms arise from over-exertion of the muscles, as is often the case, artificial support may be given with advantage to the particular muscles. Friction over the seat of pain, and the application of stimulants, as turpentine, ammonia, and brandy, in the form of embrocation with oil or glycerine, has been found very beneficial. Where the pain is very acute, or the muscular action excessive, sedatives, as opium, henbane, and belladonna, may be given internally and applied externally.

(Laycock *On the Nervous Diseases of Women;* Bennett, *The Principles and Practice of Medicine;* Inman, *The Phenomena of Spinal Irritation.*)

SPINET, a musical instrument of the harpsichord kind, but differing in shape and power, formerly much in use, though now entirely superseded by the piano-forte. The *Spinet* had but one string to each note, which was struck by a quilled jack, the latter acted on in the usual manner by a key. The tone was, of course, comparatively weak, but pleasing, and as the instrument was small in dimensions and cheap in price, it answered the purpose of those who did not find it convenient to purchase a harpsichord. The outline of its ordinary form was nearly that of a harp laid horizontally, supposing the clavier, or key-board, to be placed on the outside of the trunk, or sounding part, of the last-named instrument.

SPINNING. There are two entirely distinct manufacturing operations to which this name is given—the one relating to animal and vegetable fibres, and the other to certain soft metals.

Fibre Spinning.—This kind of spinning consists in forming a flexible cylinder of greater or less diameter, and of indeterminate length, out of vegetable or animal fibres, arranged as equally as possible alongside and at the ends of each other, so that, when twisted together, they may form an uniform continuous thread. The primitive modes of spinning by the spindle and distaff, and by the spinning-wheel, which are still extensively practised in the East, and not entirely superseded in some remote districts of Scotland, only enable the spinner to produce a single thread; but with the almost automatic spinning-machinery which has been called into existence by the cotton manufacture, one individual may produce nearly two thousand threads at the same time. The history of the series of inventions by which this result has been gradually attained has been already given under COTTON MANUFACTURE; together with wood-cuts and descriptions of some of the chief machines. The spinning of flax, silk, and wool partake of the same general character as that of cotton; so far as they differ they will be found noticed under LINEN MANUFACTURE; SILK MANUFACTURE; and WOOLLEN AND WORSTED MANUFACTURE.

Metal Spinning.—This is a peculiar branch of Birmingham and Sheffield manufacture, in which articles of use and ornament are produced without forging, casting, stamping, or cutting, by bringing into play the ductility of the metal. The metal employed is chiefly one or other of the soft mixed white metals, such as Britannia metal. Teapots, and such-like articles, are shaped in this metal almost entirely by the process of spinning. There is first prepared a wooden mould, of the exact size and shape; and this mould is fixed upon a lathe. Then a circular piece of the thin sheet metal is taken and fixed temporarily in contact with the bottom or flat surface of the lathe. Burnishers and smooth tools are then pressed cautiously against the metal, while the mould is rotating, and made to conform to all its curvatures—stretching out a little to cover the convexities, and compressing a little to cover the concavities. The ductility of the metal alone enables it to do this; the bending takes place gradually, so as to enable the particles of the metal to accommodate themselves to their altered position. Teapots, plated candlesticks, dish-covers, bell mouths of musical instruments, &c., are made by a succession of processes of which this is the chief; and a large quantity of cheap Birmingham jewellery is worked into form in a similar way.

SPIRAL, a name belonging properly to curves which wind round a point in successive convolutions. The easiest mode of representing such curves algebraically is by means of polar COORDINATES: hence, in many of the older English works, any curve referred to such coordinates is said to be considered as a spiral. Thus we have the circle considered as a spiral; the ellipse considered as a spiral, and so on. The rest of this article is intended only for those who have some knowledge of the mathematical part of the subject.

If r be the radius vector of a curve, θ the angle which it makes with a given line, and $r=\phi(\theta)$ the equation of the curve, it is obvious that if $\phi\theta$ be a common trigonometrical function of $\sin\theta$, $\cos\theta$, &c., the curve will not have an unlimited number of convolutions. The whole of the curve from $\theta=2\pi$ to $\theta=4\pi$, will be merely a repetition of that from $\theta=0$ to $\theta=2\pi$. Thus, $r=\sin\theta$ is the equation of a circle of a unit diameter, tangent at the origin to the line from which r sets out; the fifteenth half-revolution of the radius vector is only the fifteenth description of this circle. It is then only when the angle θ occurs independently of trigonometrical quantities, that any curve is represented which can properly be called a spiral. Thus, the spiral of Archimedes, or Conon, of which the equation is $r=a\theta$, has a convolution in which r changes from 0 to $2\pi a$, while θ changes from 0 to 2π; another, in which r changes from $2\pi a$ to $4\pi a$, while θ changes from 2π to 4π, and so on. The principal spirals to which distinct names have been given, are—

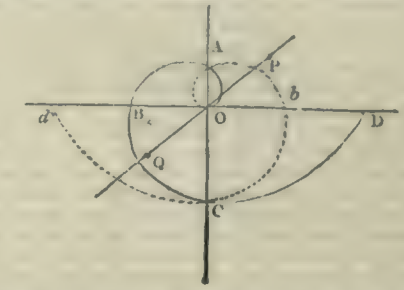
	Equation.
1. Spiral of Archimedes . . .	$r=a\theta$
2. Reciprocal Spiral	$r\theta=a$
3. Lituus	$r^2\theta=a$
4. Logarithmic or Equiangular Spiral	$r=ab^\theta$

with some others of less note. The figures of these spirals are given in all books on the application of algebra to geometry.

It has hitherto been universal to consider spirals in a manner which has deprived these curves of half their convolutions; this has been done by refusing to entertain negative values of the radius. For example, in the spiral of Archimedes $r=a\theta$, a being a positive quantity, the curve is supposed to have no convolutions when θ is negative, or when the radius revolves negatively. The consequence is, that the curve begins abruptly at the origin. It would be a matter of little importance to insist on the existence of the additional branches which belong to the negative radii, if it were not that the other mode of representing curves, by means of rectangular coordinates, always gives the additional branches: so that, if we refuse to receive the latter as coming from the polar equation, we have only the alternative of supposing that the mere transformation of coordinates destroys a part of the curve. In the spiral of Archimedes, for example, the rectangular and polar equations are—

$$y = x \tan \frac{\sqrt{(x^2+y^2)}}{a}, \qquad r = a\theta.$$

The first, treated in the usual way, gives a curve of which there is



one succession of convolutions beginning with O A B C D, and another beginning with O A b C d. But the second equation, which is only the first in a different form, does not yield any of the second set of convolutions, unless by means of the negative values of the radius vector answering to negative values of θ.

The manner in which the negative value of r is to be treated, is as follows:—Every line passing through the origin, as P O Q, makes two angles with the positive side of the axis of x, P O D, less than a right angle in the diagram, and Q O D, between two and three right angles: the second of which may be considered as the common angle Q O D, taken negatively. The bounding directions of these angles are different, O P and O Q: the rule is, whichever angle the straight line Q O P is supposed to make with O D, let the bounding direction of that angle be the positive direction, and the other direction negative. Thus, when P O D is the angle, O P is positive and O Q negative: when Q O D is the angle, O Q is positive and O P negative. In this manner it will be found that the first three of the four spirals above enumerated have never been completely drawn. There is little need to insist much on the necessity of the extension here described: one more instance may suffice. Let the reader trace the curve whose equation is—

$$2y^2 = 1 - 4x - 2x^2 \pm \sqrt{1-8x},$$

derived from $r=1-2\cos\theta$. The rectangular equation gives a curve of two loops, of which the polar equation will only yield one, unless negative values of r be employed, in the manner above described. Nevertheless, if the process had been inverted, and the polar equation deduced from the rectangular, we should have found $r=\pm 1-2\cos\theta$ for the former; and the effect of the double sign is that the positive values of r only, in the two equations $r=1-2\cos\theta$, and $r=-1-2\cos\theta$, will give the complete curve deduced from the rectangular equation. As far as this instance goes, it might seem as if the complete polar equation, as reduced from the rectangular, would give the whole curve by means of positive radii; though at the same time a single instance hardly proves anything. But even granting that the passage from the rectangular to the polar equation will always give forms enough to the latter to trace the whole curve from positive radii, it remains indisputable that the other transition, from the polar to the rectangular, requires the negative radii to be taken into account.

SPIRAL OF ARCHIMEDES. [SPIRAL.]

SPIRE (in German, *Spitze,* or *Thurm-spitze;* in French, *Flèche*), in Gothic architecture, is used to designate the tapering pyramidal mass erected on a tower by way of finish and ornament. The origin of the spire, like that of the pointed arch, is merely matter of conjecture. The probability is that it arose out of the peaked roof usually given to campaniles and towers of a preceding period, which form was afterwards gradually improved upon and refined, till it eventually grew up into the slender tapering spire. The tower of Than church, Normandy, engraved under NORMAN ARCHITECTURE, may be referred to as an example exhibiting the rudiments of the spire, it being no more than a steep peaked roof or low pyramid, whose height does not exceed three-fourths of its base. A *peak* of this kind differs also from the spire both in being the same in plan as the tower on which it is placed, and in being immediately set upon it, whereas the spire is almost invariably an octagon or other polygon, and is surrounded at its base with a parapet. In Italy, where campaniles are usually detached square towers of very slender or lofty proportions, the spire is almost unknown, for such towers have seldom more than a mere pyramidal roof or peak. There are some few instances of square spires; among them a very singular one at Egeln in Germany, where two such spires are set immediately together upon the same tower. But however slender in their proportions such spires may otherwise be, they have a certain heavy massiveness of form. When therefore greater loftiness and lightness were aimed at in this feature, the adoption of a polygonal plan for it became almost matter of course; for although in a geometrical drawing the general outline and proportions of a spire are the same whether it be square or octangular in plan, the perspective or actual appearance is widely different; because in the latter case the diagonal breadth of the square tower below is cut off, and each side or plane of which the spire is composed becomes a much more pointed triangle. Besides which, the polygonal spire produces a degree of contrast and variety highly favourable to general effect in the Pointed style.

A gradual and progressive transition from the mere peak or pyramidal roof to the slender tapering spire, cannot, however, be clearly traced. On the contrary, some of the earliest deviations from the simple pyramidal form appear to have produced uncouthness rather than lightness; for although much greater loftiness upon the whole was so occasioned, the appearance of it was reduced by the sides of the tower being made to terminate in gables cutting into, and therefore partly cutting off, the base of the pyramid or spire itself. Many of the earlier German edifices contain examples of this peculiarity—one almost confined to them; among others the cathedrals of Worms and Gelnhausen, the church at Andernach, and that of the Apostles at Cologne, exhibit many varieties of spires, or rather *spire-roofs*, springing up from gables at their base: and in some the gables are so large, and rise up so high, that the appearance of spire is almost entirely lost. Such is the case with the pyramidal covering of the square tower at the west end of the church at Gelnhausen, of which the portion above the gable forms a mere capping. In this country the spires in the First Pointed, or Early English style, were usually much less acute than in those of the Second Pointed period, when this feature arrived at its greatest perfection both in design and decoration. The outline of spires of this Second Pointed period is commonly very graceful and refined, a well-considered entasis being often given: the spires of Salisbury Cathedral and St. Mary's Church, Oxford, are well known and admirable examples of this period.

Spires vary much in character. In this country a spire set immediately upon a tower without any parapet, &c., at its base, is technically described by the term *broach*. There are indeed so many peculiarities in spires, that it is highly desirable to have descriptive terms for them. First, as regards its base, a spire may be said to be *cluster-based* when surrounded below with pinnacles connected with it, and from among which it seems to spring up; of which kind St. Mary's, Oxford, is a celebrated example. The Hôtel-de-Ville, at Ypres, has a spire clustered with four exceedingly tall pinnacles or lesser spires. Where there are windows placed *against* a spire, rising *upright* like the dormers or lucarnes on a roof, the term *Lucarned* would express that character; we have therefore not scrupled to make use of it in the annexed table of spires, where it is applied, among others, to those of Lichfield cathedral, which have several tiers of such windows, and are described accordingly. Where the height does not exceed two diameters of its base a spire might not inconveniently be termed a *stump-spire*. *Crocketed* and *banded* are terms requiring no explanation; but in regard to the first it may be remarked, that spires, otherwise quite plain, are sometimes ornamented with *crockets* along their edges; and with respect to *bands*, they are sometimes little more than string-mouldings, but in other cases broad and enriched surfaces. Many of the spires in Normandy are ornamented with such a number of bands, that they form alternating courses with the plain spaces between them. *Finialled* is a term which does not apply to any of our English spires; but that of St. Stephen's, Vienna, and some other continental spires, have an exceedingly large and rich finial, which ornament gives them a particular boldness of expression. The *Tabernacle-spire* also is one of which there is no example in this country, but of which the one just mentioned, and those of Strasburg, Ulm (as designed), Thann in Alsace, and many others, are specimens, the tower and spire being carried up from the ground in a succession of diminishing stages, all profusely adorned with pannelling, niches, canopies, pinnacles, and other tabernacle-work, in such a manner that it is barely possible to distinguish where the upright portion or tower terminates, and the spire itself begins, the latter seeming little more than the uppermost stage in continuation of the rest. Neither have we any instances of *Open-work* spires, or of such as, if not actually perforated, are yet entirely covered with tracery. That at Freyburg, and those at Burgos and Batalha, are exceedingly rich specimens of the kind. The chapter-house of Burgos also has a series of very large pinnacles or small spires of tabernacle character. Cambrai and Esslingen on the Neckar afford other examples of open-work spires.

There are various other circumstances which, though they do not affect the spire itself, produce greater or less difference in regard to the character of the structure of which it is a component feature. Very much, for instance, depends upon its situation in the general plan: at

TABLE OF SPIRES, ENGLISH AND FOREIGN.

	Tower.	Spire.	Total Height.	Remarks.
	Feet.	Feet.	Feet.	
Old St. Paul's . . .	260	274	534	Six diameters high.
Salisbury	207	197	404	Date about 1350. Three enriched bands. Nearly 5 diameters.
Norwich	140	163	303	Plain, rather more than 5 diameters high.
Lichfield	114	138	252	Lucarned, 5 tiers of windows. Nearly 5 diameters high.
,, two western .	89	103	192	Lucarned, 4 tiers; 4½ diameters high.
Chichester	..	..	270	Pinnacled and lucarned below; banded with two broad rich bands; else quite plain. Both tower and spire fell, Feb. 21, 1861.
Oxford Cathedral . .	94	52	146	Date about 1220.
Oxford, St. Mary's . .	86	94	180	Spire itself quite plain, lucarned with a canopied window below, on four sides. Embased by very rich canopied niches and pinnacles.
Louth	148	140	288	Embased with lofty pinnacles and flying buttresses. Crocketed. 6 diameters.
Grantham (about) . .	140	..	250	Lucarned, crocketed, large crocketed pinnacles at base. Base of spire less than tower.
Bloxham	101	94	195	A very beautiful example. Spire 5 diameters high. Date about 1350.
St. Michael's, Coventry .	136	164	300	This tower and spire a very fine example.
St. Mary's, Stamford .	..	..	..	Date about 1260. Base without parapet or pinnacles. Lucarned, 4 tiers. Spire 2½ diameters.
Cologne (as designed) . .	330	200	530	Two west spires enriched with tracery, and crowned by large finials.
Strasburg . . .	364	110	474	Two west towers, only north-west spire.
St. Stephen's, Vienna . .	285	180	465	On south side of church. Example of a tabernacle tower and spire.
Ulm (as designed) . .	320	171	491	Tabernacle example. Tower and spire in centre of west front.
Freyburg	221	159	380	Rich open-work spire. Tower and spire in centre of west front.
Marburg	184	88	272	Two west towers and spires. Base of spire gabled. Spire 4½ diameters.
Nürnberg, St. Laurence .	180	90	270	Two west towers and spires. Base of spire gabled. Spire 4½ diameters.
Nürnberg, St. Sebaldus .	170	90	260	Two west towers and spires. Base of spire gabled. Spire 4½ diameters.
Antwerp	..	..	366	Two west towers, only north-west spire.
Chartres "New Spire" .	..	..	371	Two west spires, the north-west, or "New," spire loftier and more enriched than the other.
Bayeux	142	104	246	Two west spires. The north-west spire has 6 broad bands; the other plain. Diameter at base 27 feet.
Caen, St. Stephen's . .	155	107	262	Lucarned at base and banded.
Caen, St. Peter's . .	134	110	244	Base of spire 24 feet. Spire has 9 bands, with small hexafoil, quatrefoil, and trefoil apertures between them. Crocketed.
Batalha	113	57	170	Very rich open-work spire. Diameter at base 19 feet.
Burgos Cathedral . .	..	..	280	Two short or stump but very rich open-work spires, at west end. Date of spires 1442.
Glasgow	115	105	220	Lucarned, banded, lower band richly moulded and quatrefoiled, and surmounted by fleurons. Diameter at base 27 feet.

Salisbury and Norwich, the spire is raised upon a tower at the intersection of the cross, or in the centre of the plan; whereas in most continental cathedrals and large churches there are two spires on the towers of the west front, though in some instances (Strasburg, Antwerp) only one has been erected. Several, however, have a single tower and spire in the centre of the west front (Ulm, Freyburg, Thann in Alsace), in which case the tower itself begins to diminish almost from the ground, and the whole becomes what we have described as of the *tabernacle* character. In most of our English churches (not cathedrals) the spire is placed upon a tower at the west end, as at Grantham, Louth, Bloxham, &c. If we except Peterborough, where they are very diminutive, the only English cathedral which has two western spires is Lichfield, which is further remarkable as having a central tower and spire also. Besides the richness and variety thus produced, the larger central spire serves to balance the whole composition, whereas else the body of the structure is apt to look low in comparison with the west end. At St. Stephen's, Vienna, the tower and spire are singularly placed on the south side of the edifice, it having been intended to balance them by a corresponding tower on the north side. At Gelnhausen, on the contrary, there is a group of spires at the east end.

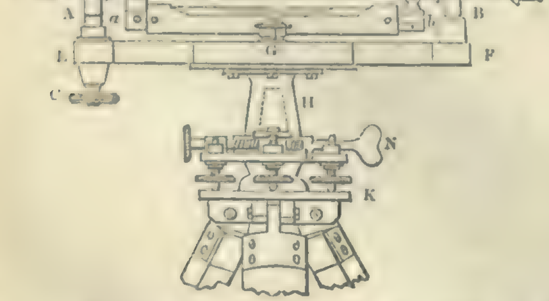
Though so much depends upon the proportion of spires to their own diameters and to the height of the towers, almost the only thing that is specified in the usual description of spires is the entire altitude from the ground, which single measurement, unaccompanied by others, gives no idea of the relative dimensions of the spire or how it is proportioned. Some of the loftiest spires, as they are popularly termed, are by no means lofty, being not above a third of the entire height, and not more than four of their own diameters. The spire of Strasburg, for instance, is only 110 feet out of 474, or less than one-third of the tower itself. At Antwerp again the spire is a mere *peak* crowning the uppermost stage of the tower, while the tower itself is twice as high as the roof of the church. If we compare Salisbury with Norwich, the spire of the latter cathedral will be found, though of less dimensions, much loftier in relation to the rest than the other, being in the ratio of 163 to 308 feet, while Salisbury is only 197 to 404. We have, therefore, drawn up a short table of spires (see preceding page) showing, where we can, the separate as well as united heights of the respective towers and spires.

SPIREIN. ($C_{42}H_{24}O_{20}$?) The yellow colouring matter of the meadow-sweet (*Spiræa ulmaria*). It is a crystalline yellow powder insoluble in water, but very soluble in alcohol and ether. The dilute solution is yellow, but becomes dark green on concentration. It possesses a slight acid reaction, and cannot be volatilised without decomposition.

SPIRIN. [SALICYLIC GROUP.]

SPIRIT, a term used in chemistry. When employed alone, it is now almost exclusively applied to spirit of wine, or alcohol; formerly however the name spirit was given to most substances capable of being vaporised and condensed by distillation, and to some not obtained by distillation. It will be requisite merely to name a few of those compounds to show how extensively it was used in naming substances of very different origin and composition: thus nitric acid was called spirit of nitre: hydrochloric acid, spirit of salt; sulphuric acid, spirit of sulphur; chloride of tin, spirit of Libavius; solution of ammonia, spirit of sal-ammoniac, or sometimes spirit of hartshorn.

SPIRIT-LEVEL, a tube of glass nearly filled with spirit of wine or distilled water, and hermetically sealed at both ends, so that when held with its axis in a horizontal position, the air which occupies a part not filled with the spirit or water places itself contiguously to the upper surface. The tube being supposed to be perfectly cylindrical, the exact horizontality of its axis is ascertained by the extremities of the air-bubble being at equal distances from the middle point in the length of the glass.



The spirit-tube is used in determining the relative heights of ground at two or more stations, and in order to render it available for this purpose, it is placed within a brass case having a long opening on the side which is to be uppermost, and is attached to a telescope; the telescope and tube are then fitted to a frame, or cradle, of brass, which is supported on three legs. In the interior of the telescope, at the common focus of the object glass and eye-glasses, are fixed, generally, two wires, at right angles to each other, their intersection being in the line of collimation, or that which joins the centres of all the lenses.

The case containing the spirit-tube is made to turn on a joint at one extremity, as *a*, by the revolutions of a screw, *b*, at the opposite extremity; and the telescope rests, near each end, within two arms at the top of a small pillar, A or B, the pillar and its arms resembling the letter Y, and the interior sides of the arms being tangents to the tube of the telescope. One of these pillars is made capable of a small movement in a vertical direction by turning a screw, C, at its base, for the purpose of elevating or depressing one end of the telescope and spirit-tube; and in the more perfectly constructed instruments, both the pillars may be so moved. The pillars are at the extremities of a strong brass plate, E F, the under side of which is connected with the tripod-stand, which supports the whole instrument; and a compass-box, G, is attached immediately to the plate, as in the figure, or is raised above the telescope by means of four small pillars. A hollow conical socket, H, of brass is screwed to the under side of the plate, and is intended to receive a piece of bell-metal of a corresponding form, which constitutes the upper part of the stand. This piece serves as a vertical axis, upon which the telescope, the spirit-level, and the compass are to turn round horizontally: sometimes, however, the conical pivot projects from the under part of the plate, E F, and the socket is on the stand.

The three legs which are to support the instrument are firmly fixed to a circular plate, K, perforated at its centre, and having about the perforation a hollow spherical zone, resembling a small inverted cup. In the simpler kinds of spirit-levels a circular plate, L, of the same dimensions as the last, carries above it the pivot before mentioned; and from below it projects a stem, terminating in a ball, which fits the inverted cup or socket. By means of four screws which pass through one of these two plates (the upper plate in the cut), nearly at the extremities of two diameters at right angles to one another, the upper plate is made parallel to the horizon, and consequently the conical pivot which it carries is brought to a vertical position.

The above is a general description, which will serve nearly for every spirit-level at present in use, whatever be its form; and the following is the usual manner of performing the adjustments, preparatory to the instrument being employed on the ground:—

The telescope should, by a proper opening of the legs of the stand, be at first rendered as nearly level as can be estimated by the eye; then, being turned so as to lie vertically above the line joining two opposite screws in what are called the parallel plates (K and L), the spirit-tube is brought to horizontal position by relaxing the screw nearest to its higher end, and tightening that which is opposite to it: the like operation is to be performed with the other pair of screws, after placing the telescope vertically above them. In order to render the spirit-tube parallel to the axis of the telescope, after the bubble of air has been made to occupy the middle place by the process just mentioned, let the telescope be reversed in the arms (the Ys as they are called); then if the bubble does not still occupy the middle, it must be made to do so by successive trials, endeavouring to correct half the error by means of the screw *b*, and the other half by the screw C.

The eye-piece of the telescope must be moved inwards or outwards till the wires in the field of view are distinctly seen; and the object-glass must also be moved by means of the pinion, M, till the station-staff, placed at any convenient distance (suppose 100 yards), is also distinctly seen. By a few trials, the distance between the eye and the object-glass may be made such that the intersection of the wires will appear to remain constantly at one point on the staff while the observer in looking through the telescope varies the position of his eye. It is necessary besides that the intersection of the wires should be precisely in the line of collimation, or the optical axis of the telescope: for this purpose the point of intersection should be directed to some well-defined mark at a considerable distance. The telescope must then be turned on its axis; and if the intersection remains constantly on the mark, that adjustment is complete; otherwise it must be rendered so by means of the screws, *c d*, &c., on the telescope; those screws being placed at the extremities of two diameters at right angles to one another, on being turned they move the plate carrying the wires in the directions of those diameters. In order that the correction may be made, the apparent displacement of one of the wires, in consequence of the telescope being turned half round on its axis, should be observed, and the screws turned till half the displacement is corrected; the like observation and correction may then be made for the other wire: a few repetitions of each adjustment will probably be necessary before the error is wholly removed.

The level constructed by the late Mr. Troughton differs from that which has been above described in having the spirit-tube sunk partly in the telescope; and the latter, being incapable of a movement about its axis, does not admit of a separate adjustment for the intersection of the wires.

Mr. Gravat, who made considerable improvements in the mechanism of these instruments, recommends the following method by which the error in the positions of the cross-wires and spirit-tube may be ascertained and corrected:—Let three pickets be driven into the ground in a line and at equal distances from one another, and let the spirit-level be set up successively in the middle between the first and second, and between the second and third pickets; then, having by the screws of the instrument adjusted the spirit-tube so that the bubble of air may retain the same place while the telescope is turned round on the vertical axis, direct the object-end of the telescope successively to the station-staves held up on the different pickets, read the several heights, and take the differences between those on the first and second, and on the second and third staff. Now the staves being at equal distances from the instrument, it is obvious that any error which may have existed in the line of collimation, or from the spirit-tube not being parallel to that line, will be destroyed, and the differences between the readings on the staves are the differences in the levels of the heads of the pickets; but unless the adjustments are perfect, this will not be the case if the instrument be set up at any point which is unequally distant from all the pickets; therefore from such point direct the telescope to the staves, and take the differences of the readings as before. On comparing these differences with the former, a want of agreement will prove that the intersection of the wires is not in the optical axis: and the error may be corrected by means of the screws belonging to the wire plate. After the agreement has been obtained, should the bubble of air not stand in the middle of the tube, it may be brought to that position by the screw *b*, at one extremity of the case, and the instrument is then completely adjusted. (Simms, 'Treatise on Mathematical Instruments.')

The spirit-level is usually provided with a clamp, N, and a screw, P, by which when the axis of the telescope has by hand been brought near the object, the coincidence may be accurately made by a slow and steady motion about the vertical axis.

The spirit-tube or level which is employed for the adjustment of transit telescopes or astronomical circles is contained in a case with feet or with loops at its extremities, in order that it may either rest above or be suspended below the horizontal axis of the instrument to be levelled; also the upper part of the case is furnished with a graduated scale, the divisions of which are numbered on each side of a zero point, this point being usually placed near each of the two extremities of the air-bubble when the tube is in a horizontal position. Having set up or suspended the spirit-tube, the two particular graduations at which the extremities of the air-bubble rest are marked; and half the sum, or half the difference of these numbers, according as the extremities of the bubble are in the same or in opposite directions from the two zero-points, being taken, gives the distance of the centre of the bubble from the middle between those points. The level being then reversed, the graduations at which the air-bubble rests are again marked, and half the sum or half the difference is taken as before. A mean of the two distances thus found is the true distance of the centre of the bubble from the middle point on the scale; and the screw which elevates or depresses one end of the axis of the telescope being then turned, till either extremity of the bubble has moved, in a direction contrary to that in which the centre of the bubble had moved from the middle of the scale, through a number of divisions equal to that mean distance, that axis will be brought to a horizontal position. This method is used in preference to that of successive trials, in order to avoid the trouble of making several reversions of the whole instrument.

The levelling-staff till lately in general use for finding the relative heights of ground is a rod consisting of two parts, each six feet long, which, by being made to slide on one another, will indicate differences of level nearly as great as twelve feet. The face of the rod is divided into feet, inches, and tenths, or into feet with centesimal subdivisions; and a vane, or cross-piece of wood, perforated through the middle, is moved up or down upon the rod by an assistant till a chamfered edge at the perforation is seen by the observer at the spirit-level to coincide with the horizontal wire in the telescope. The height from the ground to the chamfered edge of the vane must be read by the assistant; and it being out of the power of the observer to detect any mistake in the reading, it becomes very desirable that the graduations on the rod should be sufficiently distinct to allow the heights to be read at the spirit-level itself. The rod proposed by Mr. Gravat for this purpose is divided into hundredths of a foot by stripes which are alternately black and white, and are numbered at every foot in the usual way with figures great enough to be seen on looking through the telescope; the tenths of a foot are indicated by lines longer than the others. A similar staff has been proposed by Mr. Sopwith and Mr. W. P. Barlow; and the former gentleman, besides the number of every foot, has given a number to every first, third, fifth, and ninth decimal. Mr. Barlow's rod is also divided into centesimals of a foot; but the marks, instead of being stripes whose edges are parallel to one another, have the form of triangles: each tenth mark, however, is in the form of a lozenge, or double triangle, for the sake of greater distinctness.

SPIRIT OF SALT. [Chlorine.]

SPIRIT OF WINE. [Alcohol.]

SPIRIT THERMOMETER. [Thermometer.]

SPIRIT TRADE. [Wine and Spirit Trade.]

SPIRITUAL COURTS. [Ecclesiastical Courts.]

SPIROILIC ACID. Another name for hydride of nitrosalicyl. [Salicylic Group.]

SPIRÖILOUS ACID. Synonymous with hydride of salicyl. [Salicylic Group.]

SPIROUS ACID. Synonymous with hydride of salicyl. [Salicylic Group.]

SPLEEN, DISEASES OF THE. These do not appear to have been much studied in this country, because they do not very frequently occur; they are, however, by no means of unusual occurrence in moist climates, whether warm or temperate, as Italy, Holland, South America, and some parts of India; in fact, wherever malaria exists. The spleen is liable to many sorts of disease: Dr. Bigsby ('Cyclop. of Pract. Med.') enumerates as many as ten, but of these only the most important can be here noticed. Splenitis, or inflammation of the spleen, may be either acute or chronic; though Dr. Baillie remarks that this organ is much less subject to inflammation than many other of the abdominal viscera. ('Posthumous Lectures and Observations on Medicine,' 1825, unpublished.) Acute inflammation of the spleen, together with heat, fulness, and tenderness in the splenic region, with pain upon pressure, is accompanied with the usual pyrectic signs, and often with a pain extending over the whole of the abdomen, but particularly in the left side, and shooting from the diaphragm to the left shoulder. There is also not unfrequently a dry short cough, and sense of constriction in the præcordia, sickness, or nausea, and a discharge from the rectum of black or livid blood, from a rupture of some of the splenic vessels. Of this disease a remarkable instance, which terminated in nine days, has been recorded by Dr. Ley, in the 'Transactions of the College of Physicians of London' (vol. v. p. 304). The texture of the spleen after death was in this case so altered as to resemble an extremely soft piece of sponge, of which the cells had been filled with an intimate mixture of pus and grumous blood. On placing it in water, innumerable vessels, as fine as the fibres of swans' down, floated separately, rising from every point of the superficies of the organ. The contents of this spongy mass having been removed by repeated washings, something like an attempt at the formation of cavities to contain the matter manifested itself. No regular cyst however had been formed. All the other viscera, abdominal and thoracic, were healthy, except the uterus, whose inner surface was gangrenous. The common causes of inflammation of the spleen are much the same as those of inflammation of the liver, namely, suddenly suppressed perspiration, especially from currents of cold and damp air, and excess of spirituous potation; sometimes, however, the cause is too obscure for detection. With respect to the treatment, the usual antiphlogistic remedies may be employed, but promptly and energetically. Dr. Baillie says, he is not aware that inflammation of the spleen would require a different treatment from that of other viscera.

If after a certain period the inflammation do not yield, it assumes the chronic form, in which the variation in the severity and duration of the complaint is very great. If it has accompanied ague, the symptoms may possibly not have been urgent in the outset, but it is almost always a painful as well as formidable disease. It commonly lasts for some months, and may continue for years with remissions. With respect to the terminations of chronic splenitis, resolution does not take place often; suppuration is also rare upon the whole, and Dr. Baillie says he "had never met with an abscess in the spleen in all the dead bodies which he had examined." When pus is formed, it is of the ordinary creamy kind, but is sometimes concrete; it varies in amount from a few ounces to many pounds. The matter may find its way into the stomach, colon, or peritoneal cavity; it may burst into the left side of the chest, or into the lungs, inducing symptoms of phthisis; or it may empty itself outwards through the abdominal walls. Ossification of the spleen after inflammation is rare, as is also gangrene; softening, induration, and hypertrophy, especially the last, are much more common. With respect to the treatment of chronic splenitis, perhaps the best plan that can be adopted is the combination of aperients with iron and sedatives; the good effects of mercury in this disease being now generally considered precarious, trivial, and at best temporary. Local applications, such as cupping, issues, setons, &c., are sometimes productive of great benefit.

Besides the inflammatory softening of the spleen, there is another of a character quite peculiar, and unattended by any of the characteristics of inflammation, wherein the structure of the spleen is more or less destroyed, and it is often reduced to a simple bag, containing a substance which varies from the state of clotted or grumous blood to that of tar. This was very frequent in the Walcheren fever, in which cases the spleen was usually found after death of great size, and generally a mere bag filled with a liquid like tar, and weighing from three to five pounds.

One of the most common diseases of the spleen is hypertrophy, the most usual causes of which are ague and remittent fever. It is therefore chiefly to be found where these are endemical, but it is not very uncommon in any part of Great Britain. The size which this organ sometimes attains is enormous, and it is surprising to find how long persons can carry about with them very enlarged spleens, and at last die of some other disease. Dr. Bigsby quotes from Lieutaud the case of a woman who had for seventeen years a spleen weighing thirty-two pounds; similar facts are to be found in Haller. Dr. Baillie mentions ('Posthumous Lectures') having met with cases where it was so large as to occupy nearly all the left side of the abdomen, extending from the diaphragm to the pelvis. When the enlargement is so considerable that the lower end of the spleen can be felt under the margin of the ribs upon the left side, there can be no doubt with respect to the disease. When the hypertrophy does not reach this extent, its most characteristic symptoms, are a sense of weight in the left side, with or without evident swelling; inability to lie with ease on the right side; debility, without corresponding emaciation; disordered stomach, irritable bowels, dry cough, and absence of fever. The spleen, when enlarged, is always felt to be harder than in a natural state, but pressure upon it with the hand seldom produces pain. An hypertrophy of the spleen is sometimes followed by ascites; but there will frequently be no dropsy of the abdomen, even where this organ has been for a long time much enlarged. When this form of disease has been connected with ague, it more frequently subsides than in any other case; and the quina, which has been prescribed to cure the latter affection, will probably be serviceable also to the former. "When the enlargement has taken place independently of this cause," says Dr. Baillie, "it hardly ever subsides of itself, or is materially diminished by medicine. According to my experience, mercury, administered both externally and internally, produces very seldom any good effect; I have seen, I think, more advantage from a seton inserted under the skin which covers the spleen. In some cases it has appeared to be diminished in size by this remedy, and to be rendered softer; but I do not recollect a single instance, except after ague, in which it has been reduced to nearly its natural size. Temperate living, abstaining from violent exercise, and keeping the bowels open, must be to a certain degree useful in retarding the progress of the disease." The remedy largely employed in India for the cure of chronic tumour of the spleen is a compound of garlic, aloes, and sulphate of iron. When emaciation and diarrhœa are present, the garlic and aloes are macerated in brandy; under other circumstances, in vinegar. The proportion of aloes is so regulated as to produce three evacuations daily; and the medicine also produces copious secretions from the kidneys. The *Decoctum Aloes Compositum* with the *Tinctura* or *Acetum Scillæ* would probably prove equally effectual. The moxa, and even the actual cautery, have been recommended for this disease; and emetic cataplasms of tobacco-leaves, renewed constantly so as to keep up frequent vomiting, have in some instances produced the happiest effects.

Atrophy of the spleen is by no means so common as hypertrophy; and though some instances are related by modern writers, yet their statements are so meagre and unsatisfactory, that no use can be made of them. It is sometimes found exceedingly small and even shrivelled when some other organ is much enlarged, where there have been great discharges of blood, in ascites, and in extensive chronic disease. This form of disease of the spleen obviously admits of no remedy.

Hydatids in the spleen are found now and then, but not very often; Dr. Baillie had never met with a single case of them. It is hardly possible to discover their existence during the life of the patient, nor, even if it were more easy, could the complaint receive any cure, or even amendment, from medicine. The disease arises quite unconsciously to the patient; the first intimation of its existence being debility, dyspepsia, and the uneasiness created by a slowly increasing tumour, which in its progress causes further derangement by compression and displacement of other organs, and becomes itself perceptible externally. It is only when the containing membrane, or some organ, becomes inflamed, that fever, pain, and their fatal consequences ensue. Hydatids may prove fatal by passing into the peritoneal cavity from ulceration of the containing sac, or by disturbing the circulation, or by irritating other viscera; or the patient may live very long with this complaint, and die eventually of another disease during the indolent continuance of this.

Melanosis and calculi of the spleen are noticed shortly by Dr. Bigsby, but the instances are too rare to require any particular remarks here.

Rupture of the spleen from some external violence occurs not unfrequently; but in the majority of cases the injury is so overwhelming that little is left for the medical practitioner to do. Free venesection and perfect rest have occasionally saved life; but in many instances the patient dies in a few hours. In these latter cases the symptoms are great shiverings, coldness of body, vomiting, and other signs of extreme collapse: when there is time and strength for reaction, there is considerable fever, with a remarkable heat of skin, and great pain in the left side or all over the abdomen; the stools and urine are not materially affected.

(Good's *Study of Med.*; Gregory's *Theory and Pract. of Med.*; Bigsby, in *Cyclop. of Pract. Med.*, from which works, with Dr. Baillie's (posthumous) *Lectures and Observ. on Med.*, great part of the pathological part of this article is taken.)

SPLINT is a piece of wood or other rigid substance which is used in surgery to maintain any part of the body in a fixed position, and especially for the purpose of holding steadily together the portions of a fractured bone. Splints vary almost infinitely in form and size, according to the part to which they have to be adapted, and the position in which it is to be held; the number and the arrangement of them in each case are equally subject to variation; nor can a surgeon have a better rule than that of following no general plan, but of determining in each case the apparatus best fitted for its peculiar exigencies. [FRACTURE.] The material of which they are commonly made is light wood; each splint consisting either of one piece cut nearly to the form and size of the limb, or of several pasted together with a strap of linen so as to be flexible in one direction. In some cases tin is a preferable material; in some stiff pasteboard. In many cases also it is very advantageous to adapt the splints exactly to all the irregularities of the limb; and as this cannot be done with wood or any unyielding material, it is usual to employ one which, being applied moist and soft, gradually hardens. Stiff pasteboard will sometimes be sufficient, especially for children; but a better material for general use is sole-leather or gutta percha, applied while quite pliant after having been well soaked in hot water, and then bandaged closely to the limb and allowed to dry. Another plan of this kind now much employed is to form a splint of linen and some glutinous material, such as starch, or a mixture of white of egg and flour, or of mucilage of gum-arabic and whiting, made as thick as bird-lime. In using these, the limb or other part should be thinly padded with soft lint; then strips of coarse linen soaked in the tenacious material should be laid on, one over the other, till on each side of the limb they form a layer about as thick as a common wooden splint. The whole should then be surrounded with a neatly-applied bandage soaked in starch. When dry, splints of this kind will so exactly fit the part to which they are applied, and be so rigid, that a patient may with safety execute the slighter natural movements of a limb within a fortnight after it has been fractured. All the further care of a simple case of fracture will generally consist in the occasional replacement of the starched bandage, and the adaptation of the splints, by cutting their edges, to the change of form which the limb may undergo as the swelling diminishes. Splints of this kind however must not be applied till all the inflammation immediately consequent on the fracture has ceased. See Druitt's 'Surgeon's Vade-mecum.'

SPONDEE (*spondeus*, *σπονδεῖος*) is a foot which consists of two long syllables (- -). The name is derived from *σπονδή*, a libation, as the metrical prayers on such an occasion were generally of a slow and solemn movement. To produce this solemnity the spondee is often used instead of a dactyl in the hexameter or pentameter: and in iambic, trochaic, or anapæstic metres, instead of an iambus, trochee, or anapæst. There is no metre which consists of spondees alone, and indeed such a metre would be very disagreeable, even if it were possible; but spondees produce a good effect when mixed with other feet. An hexameter verse which has a spondee in the fifth place, is called a spondaic verse.

SPONGIA, MEDICAL USES OF. The use of sponge by surgeons, in its natural state, to absorb fluids, needs no notice, but it is also employed by them under the name of sponge tent, when prepared in a particular manner. This consists in dipping the sponge in melted wax, and compressing it between iron plates till it hardens on cooling; it is then cut into cylindrical or other forms. The pieces are introduced into sinuses and other narrow canals, with the intention of dilating them by the expansion of the sponge, when the wax melts by the heat of the part. Sponge tents are however little used by modern surgeons.

According to the analysis of Hornemann, sponge consists of a substance similar to osmazome, animal mucus, fat oil, a substance soluble in water, a substance only soluble in potash, and traces of chloride of sodium, iodine, sulphur, phosphate of lime (?), silica, alumina, and magnesia.

When sponge has been cut into pieces, beaten in order to free it from little stones and shells, and burnt in a closed iron vessel, till it is black and friable, it is then called *burnt sponge* (*spongia usta*). As the virtues of this greatly depend on the proportion of iodine contained in the sponge, much of which is volatilised by the high temperature required in calcination, it has been proposed only to expose it to such a heat as will thoroughly dry, colour it brown, and render it friable, when it may be powdered, and preserved in well-closed bottles. For use it is generally formed into an electuary or into lozenges. A test of its goodness consists in heating it in a glass flask with sulphuric acid, and if copious violet-coloured fumes be evolved, this proves that it contains much iodine. Burnt sponge has been almost completely superseded in the treatment of bronchocele and scrofula by iodine and its preparations; but as it obviously consists of a natural combination of many of the principles which have been deemed useful in scrofula, it ought not to be hastily discarded. It is with great propriety retained in the Dublin Pharmacopœia.

SPONTANEOUS COMBUSTION. [COMBUSTION.]

SPORADIC (the Greek word *σποραδικός*, with the termination dropped) is a term applied to any disease which, being usually epidemic or contagious, occurs at any time in a few persons, without spreading extensively through a district. For example, in the year 1841 several cases of *sporadic* cholera occurred; that is, several persons, at different times and in different parts of the country, were affected with a disease in no respect different from the cholera which raged as an epidemic in 1832; but it did not spread beyond them by contagion, nor did it attack a number sufficient to give it the character of an epidemic. The circumstances on which the occasional occurrence of diseases that are usually epidemic, in a sporadic form, depend, are altogether unknown.

SPOUT, WATER. [WATER SPOUT.]

SPRAIN, or STRAIN, is an injury of muscular or tendinous tissues, resulting from their being forcibly stretched beyond their natural length. Its ordinary consequence is, after the first pain is gone by, to produce some degree of swelling, and a considerable dull aching pain of the injured part, which is greatly increased by any movement of it. These signs are due to an inflammation of the sprained tissues, which partakes of the slowness and obstinacy that characterise all the diseases of the tendons and ligaments, and which, if not early and duly attended to, frequently terminates in thickening, rigidity, and even more serious disorganisation of them and the adjacent parts.

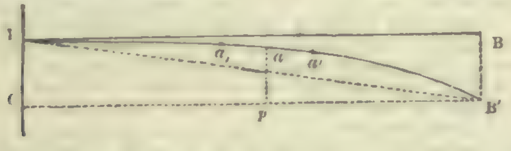
The treatment to be adopted for sprains is the immediate application of leeches, in number proportionate to the severity of the injury and the importance of the part. They should be repeated till the pain and swelling are distinctly decreased: the part should be kept perfectly at rest and cool, and the patient's general health should be kept or made good. When the pain has nearly ceased, and there remains little more than stiffness of the injured part, stimulating liniments (the common soap liniment, or a mixture of hartshorn and oil, for example) may be used.

SPRING. [SEASONS, CHANGE OF.]

SPRING, in Mechanics, is an elastic plate or rod, which is employed as a moving-power, or a regulator of the motions of wheel-work; also to ascertain the weights of bodies, or to diminish the effects of concussion.

The elder Bernoulli was the first whose attention was directed to the curvature assumed by elastic bodies, and he succeeded in resolving the problem in the case of a rectilinear plate being fixed at one end and bent by a weight applied at the other: it being assumed as a principle that, at any point in an elastic body, the force by which the body when bent by any power endeavours to recover its previous position is proportional to the angle of contact at that point; that is, to the angle which a tangent to the curve surface of the body makes, at the point, with that surface.

In order to give some idea of the manner in which the effects of elasticity are to be determined mathematically, let A B be a thin elastic plate immovably fixed at A, and bent into the form A B′ by a power P applied at B, and let $a_, a$, $a a'$ be two consecutive elementary portions of the bent plate: let also E represent the unknown force of elasticity acting perpendicularly to $a a'$ by which that element tends to recover the direction $a_, a$, from which it has been made to deviate by the power at B; and for simplicity let it be supposed that this power acts in the direction B′ C parallel to A B. Let fall $a p$ perpendicularly on B′ C; also represent B′p by x and $a p$ by y. Then, by mechanics $P.y$ expresses the momentum of the power at B′ to bend the plate at a, and in the case of equilibrium we have $P.y = E$. But E varies with the angle of contact, or the angle between the element $a a'$ and $a_, a$ produced, and that angle in any part of A B′ varies inversely with the radius of curvature at that part; therefore let r be the known radius of curvature at a point where the force of elasticity is given, and let this force be represented by e: also let R be the radius of curvature at a point, as a, where the force is represented by E. Then $\frac{1}{r} : e :: \frac{1}{R} : E$, or $\frac{er}{R} = E$, and putting E′ for er, we have $P.y = \frac{E'}{R}$. Substituting in place of R the differential expression for the radius of curvature, the elastic force might be obtained by the processes of integration. The integral, however, can only be obtained approximately.



If the elastic plate were in a vertical position with its lower end A resting on an immovable object, and a weight P, applied at the upper extremity B′, were to act in a direction towards A, the equations of the curve, approximately determined, are (the deflection being small)

$$y = \Delta \sin x \left(\frac{P}{E'}\right)^{\frac{1}{2}}, \text{ and } L = \left(1 + \frac{P.\Delta^2}{4E'}\right)h,$$

where x is any abscissa from B′ on the line B′A, y is the corresponding ordinate, Δ is the greatest deflection, or the ordinate at the middle point in B′A, h = B′A, and L is the length of the curve line AaB′: also the greatest weight which the plate or spring will bear without bending when pressed in that direction is expressed by $\frac{E'\pi^2}{L^2}$. ($\pi = 3{\cdot}1416$).

If P exceed by a small quantity the value of $m^2 \frac{E'\pi^2}{L^2}$, where m is any whole number whatever, the spring will make several bends crossing the straight line A B′ in $m - 1$ points between the two extremities.

When the elastic plate, in a horizontal position, is fixed at one end, as A, and the weight P, applied at the extremity B′, acts always vertically, the equation becomes (the deflection being small)

$$y = \frac{1}{E'}\left(\frac{1}{6}Px^3 + Cx\right)$$

where C is the tangent of the angle of contact at B′. If, on account of the smallness of this angle, C be neglected, it will follow, when x is made equal to B′C, that the whole deflection A C or B B′ will vary nearly with the weight P, and with the cube of the length of the spring.

The use of a spring as a moving-power may be best exemplified in its application to watch-work. The main-spring of a watch is a thin and narrow plate of well-tempered steel, which is coiled in a spiral form: one of its extremities is attached to a pivot or axle, and the other to the interior circumference of the cylindrical box in which it is contained. In being wound, the spring closes round the axle, and afterwards, in the effort by its elasticity to recover its former position, it turns the cylinder in a contrary direction: thus the chain which is attached to the exterior circumference of the cylinder and to the fusee causes the latter to revolve.

A slender and highly elastic spring of a like form is employed to produce a vibratory motion in the *balance* ring of a watch: one extremity of the spring is attached to the axle of the balance, and the other to some part of its circumference. If a movement of small extent about the axle be given in one direction to the balance, the spring will be compressed near the axle, and, in the effort to recover its previous state, the balance-ring will be moved round in a contrary direction; but the force of elasticity carries any point in the ring beyond the place which it occupies when the ring is in a state of rest; and when that force is destroyed by the compression again produced in the spring, near the axle, the balance is made to return in the direction in which it was first moved. Thus an alternate motion in the balance-ring is continued; the time of the vibrations, and consequently the velocities with which the wheels revolve, depending upon the force of elasticity in the spring. The elastic power of the spring varies with the tension, and is directly proportional to the angle through which the spring is wound about the axle; and thus the vibrations of a spring, like those of a pendulum in a cycloidal arc, are isochronous. [ELASTICITY.] The length of the spring and the diameter of the balance are increased by heat and diminished by cold; consequently, without some compensating power, the times of vibration will vary according to the changes of temperature.

When a carriage moving along a level road passes suddenly over an obstacle, so that a point in the circumference of the wheel is in contact with the obstacle, the centre of the wheel describes a circular arc about the point of contact as a centre; and then, if the carriage is perfectly rigid, a portion of its velocity will be lost. In order to maintain that velocity, an additional force of draught would be necessary; and an expression for this additional force is investigated in Whewell's 'Mechanics' (art. 261, and the following). Part of this additional force is employed in counteracting the motion of ascent, and the remainder, which is generally much the greater quantity, in diminishing the effect of the sudden change which takes place in the direction of the motion of the carriage. This latter part may be in a considerable degree removed by the use of springs; for then, on the wheel meeting the obstacle, the suspended body of the carriage bending the springs by its weight, the centre of gravity of that body is made to describe a curve line, to which its previous rectilinear direction is a tangent; and thus the jerks which arise from movements in directions making finite angles with one another are avoided.

The force of draught required in addition to that which is due to friction, when a stiff carriage passes over a roughly paved road, varies as the square of the velocity and the height of the stones directly, and as the radius of the wheel inversely.

SPRING-BALANCE. [BALANCE; DYNAMICS; WEIGHING-MACHINES.]

SPRING CARRIAGE. The progress of a wheel-carriage, even upon the best of roads, is impeded by the wheels coming in contact with, and being compelled to rise over, undulations of surface which check their rolling motion. In many old rough pavements, owing to the openness of the joints, and the wear of the stones, the road consists of a series of blunt ridges, in passing over which the motion of the wheel can be no other than a succession of jolts. The surface of a well-made road of broken stone, when in perfect order, presents few important asperities; but when metal or broken stone has been recently laid on, it is exceedingly rough. If a rigid carriage be drawn over any of these surfaces, the irregularities which affect the path of the wheels will be communicated through them to the body, to which they will impart a jolting or vibratory motion. In a four-wheeled carriage the movement of the body will be influenced by the discordant motions of the fore and hind wheels; and it will be continually liable, owing to the imperfections of the road, to have the whole of its weight thrown upon three wheels, whereby the framework will be exposed to injurious strains. To enable it to sustain such strains, the framework must be made very strong and heavy; and the destructive and painful effect of increasing the velocity of inelastic carriages would alone have been sufficient to limit the speed of vehicles.

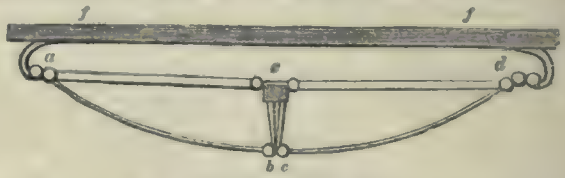
One of the simplest means of alleviating concussion is that often adopted in light carts, of suspending the seat from the sides of the body by leather straps. Next to this is the use of straps to suspend the body itself, an expedient which seems to have been occasionally resorted to from an early period. With very few exceptions, it appears that slung or suspended carriages were not used until the 17th century. In the early carriages of this kind the straps were usually attached to a framework of wood at each end of the vehicle, rising to a considerable height above the axles. The antique four-wheeled carriages of Europe used for state purposes are mostly constructed on this plan; and their great weight and slow movement prevent any violent concussion. A serious disadvantage of this construction is the great length of carriage that it renders necessary, and the cumbrous character of the wooden framework which supports the braces. The carriage must also be heavily loaded, in order to make the motion tolerably comfortable, especially when the straps are suspended from points not much higher than the bottom of the body. To remedy the defects of the primitive slung carriage, it was desirable to render the pillars from which the straps were suspended somewhat elastic. This could not be readily effected with wood, because the pillars were necessarily short, and therefore stiff. Hence arose the use of elastic steel supports, which have gradually assumed the form now well known as C-springs.

Straight springs of steel probably owe their origin to the straight wooden springs occasionally used in light vehicles in this and other countries. Used either singly or in combination, they afford sufficient elasticity for many purposes, without raising the body to an inconvenient degree, or interfering with its form; since they may be placed entirely beneath it, and require but little room for their play. *Elliptical* springs have, in some degree, the same advantages; but they require rather more depth than straight springs.

Carriage-springs are usually formed of several thin plates of steel, of various lengths, so laid and fastened together that the spring shall be thick in the centre, or at the end by which it is fixed, and thin, or consisting of only a single plate, at the end or ends where the greatest play is required. The steel used is of coarse quality, and has little carbon in its composition. It is fashioned by rolling-machinery to the transverse dimensions required, which vary from one inch and a half to three inches in width, by one-eighth of an inch to half an inch in thickness. The plate forming the back of the spring is usually thicker than the rest, on account of its being the longest, and having its ends formed into bolt-eyes, to receive the bolts by which the body is connected with it. With this exception, it is not usual to make any difference in thickness in the several plates of a spring, notwithstanding their different lengths. After the plates have been wrought into the form required, they are hardened by heating in a hollow fire, and then plunging into water. They are subsequently tempered by drawing them again through the fire, until they become so hot that a stick rubbed over the surface will be kindled to a blaze. Any accidental warping acquired in these processes is removed by hammering, the plates being slightly warm during the operation, to avoid the risk of breakage. They are then finished by filing all the parts that will be exposed to view when the spring is complete; and are finally put together and secured by a square hoop of iron, which is shrunk on hot, and by a rivet passing through the hoop and through all the plates.

Coach-makers apply distinct names to a great many varieties of springs; but those which are most generally used may be briefly enumerated. The straight spring, if single, is the *single-elbow spring*. The *double-elbow spring* is a straight spring, acting on both sides of the fixed point. It is a kind of spring very extensively used in stage-coaches, omnibuses, and light two-wheeled vehicles. *Elliptic springs* are used single in some carriages, between the axle and the framework; the spring resting on the axle, and being connected with the carriage by means of a curved bar of iron, called a *dumb-iron*, placed over it like another spring. The spring is then called an *under-spring*. Elliptic springs are often used in pairs, under the name of *nut-cracker springs*, the two springs being hinged together at each end, so as to form a long pointed ellipsis. In this way elliptical springs are much used in such four-wheeled carriages as have no perches. *C-springs* consist of two-thirds of a circle, lengthened out into a tangent; the tangent being laid horizontally, and bolted down to the framework of the carriage. When these springs are used, the body is not, as in most other cases, connected immediately with the springs, but is suspended by leather straps, which pass round the back of the springs, and are fastened to the framework near to their base. *Telegraph-springs* are combinations of straight springs in sets of four. Two are placed longitudinally, resting either immediately upon the axles, or upon the lower framework of the carriage; and two others, placed transversely, are suspended from their ends by shackles. The body is supported upon the centres of these transverse springs. *Tilbury-springs* are another combination of straight springs. Two single-elbow springs are attached to the hinder part of the body, and suspended by leather braces from a transverse spring elevated on an iron standard at the back of the framework. The front of the body is suspended from the shafts by two single-elbow springs with short leather braces; and sometimes a pair of double-elbow springs are interposed between the shafts and the axle. *Dennet-springs* are a combination of three straight springs, two of them placed across the axle, and attached at their fore ends to the shafts or the framing of the body, and the third placed transversely, suspended by shackles from their hinder extremities, and fastened to the body at its centre. The bodies of private cabriolets are usually hung upon *C-springs*, with small curved springs in front, and double-elbow springs frequently added between the shafts and the axle. The combination of springs used in under-spring carriages is the most effective which has yet been discovered for producing the minimum of concussion or motion to the passengers. The body of such a vehicle is suspended by braces from C-springs; and the framework of the carriage to which the C-springs are fastened, is supported upon under-springs, which intercept concussion from the unevenness of the road.

Of these various springs, none but the C-springs with leather braces allow universal motion to any important extent. In some carriages loops of leather or caoutchouc have been used, instead of iron shackles, for connecting straight springs, by which means the motion is rendered pleasanter, and the rattling noise of the shackles is avoided. Another defect of ordinary springs is their want of adjustibility to the weight they have to carry. They must, of course, be made strong enough to sustain the maximum weight they are intended to bear; but, by being so, they become too stiff to play easily under a light load. To meet the deficiencies of the springs in common use, Mr. Bridges Adams contrived one on the principle of the bow, which will yield in any direction, and may be made capable of adjustment, by means of screws, to a light or heavy load. This spring consists of a single plate of well-tempered steel, forced into a curved form by the tension of a chord of prepared hempen rope, or of a riband of iron or steel, and to which the axle is attached. There are two bow-springs, *a b* and *c d*, connected with each other and with the same axle. These are jointed together at *b c*, and attached to the body, of which the lower framing is shown at *f f*, by movable joints at *a* and *d*, which allow the springs to lengthen and shorten in playing. The chord of each bow is in two parts of unequal length, each of which is connected at one end with the bow, and at the other with the axle at *e*; so that the chord of the bow, *a b*, takes the direction *a e b*, and that of the bow, *c d*, the direction *c e d*. Among the advantages claimed for them are their lightness and extreme elasticity, arising from the superior quality of the steel, and the absence of the friction which attends the action of the common laminated springs.



All the springs that have been alluded to in this article are *bearing-springs*, for supporting the weight of the body of the carriage, and of the load which it conveys. In ordinary carriages no other springs are used; but in those employed upon railways, springs are also used to impart elasticity in the direction of the line of draught, so as to render the starting and stopping of the carriages gradual and easy.

SPRINGS. Rain and snow fall in quantities so unequal in different districts, and on soils which exercise upon them such various influences, that the phenomena of springs, which are primarily dependent on the penetration to some depth in the earth of water which was absorbed at the surface, are extremely complicated and curious. It is very interesting to geologists to classify and determine the causes of these phenomena, and very important in agriculture and the arts to acquire a power of directing the water currents in and below the soil and strata. The art of draining consists essentially in giving to the diffused and injurious springiness of particular soils and situations a concentrated, perhaps beneficial, current; while artesian wells relieve the hydrostatic pressure prevalent at great depths, and yield copious streams in dry lands and deserts.

As a general rule, springs are permanent in proportion to the depth to which the water which supplies them has descended from the surface; they are perennial and almost invariably constant in temperature and volume, whether hot or cold, copious or full, in situations where, from the arrangement of the mineral masses of the globe, deep subterranean channels exist for the reception of rain, and particular impediments direct and contract the passages of reflux to the surface. Such cases are common in stratified countries where jointed limestones or sandstones receive water at elevated points on the surface, and conduct it downwards below strata of clay, which are only pervious at a few points, and there permit natural discharges at lower levels than the recipient surfaces. Frequently these argillaceous strata are so nearly impervious, that artificial perforations relieve the pressure of the subterranean columns of water better than the few natural points of efflux, and thus pits and levels excavated for mines may drain springs at some distance.

On the contrary, in a country which contains narrow and frequently mixed masses of clay and gravel, or clay and sand, which cover the solid rocks, concentrated springs are almost absent, but there is a prevalent humidity and diffused springiness along the limit of the gravelly or sandy tracts. After a continuance of dry weather such springs and wetness disappear, to be renewed after the next fall of rain.

The particular points at the surface where springs, or "wells," as they are often called in the districts where somewhat of the Saxon elements of our language remains (*quelle*, in German, signifying not what is commonly understood by the English word "well," and the

French "puit," but a spring), are determined in general by one of three things :—

1. They occur at the point of lowest level, on the edge of the impervious clay which dams up the water. This happens in the cretaceous and oolitic districts of England.

2. They are often dependent on the lines of great joints, or fissures of the rocks, produced in the course of the consolidation and shrinking of the mineral masses. Large springs are thus poured out of the mountain-limestone of England.

3. The waters are directed to the surface by lines of fault, which are often quite impervious to water, and traverse the rocks in vertical or inclined planes. The hot springs of England and Wales are mostly thus circumstanced.

In general, then, the water which issues from the earth in one copious spring has been received by minute absorption on a large surface: as the living tissue of a sponge receives water by absorption through the numerous pores, collects it internally in a few channels, and rejects it by a very limited number of orifices, or as the capillaries collect blood for the veins, and these supply the heart, so the porous texture and channelled structures of rocks permit that continual circulation of water below the earth's surface, on which, in a great degree, its habitable character depends.

Between perennial or constant springs, and those which are merely dependent on the last shower of rain, the gradations are insensible, and the explanation is entirely obvious upon the general principles stated. One of the most interesting cases of this intermediate series, is that of the "intermitting" springs. It is a common circumstance on the chalk downs of the South of England (Wiltshire, Dorsetshire) for the valleys to be quite dry in one part of the year (autumn or winter), and very fully watered in another (spring, summer); the springs bursting higher up the valley in some years than in others, according to the quantity of rain which fell in some previous season (as the autumn), and the rate of its transmission through the jointed and absorbent chalk.

Another peculiarity of springs flowing out of cavernous limestone rocks is marked by a variable discharge; the springs now gush with vehemence, now subside, shrink away, and disappear. These ebbing and flowing wells are noticed in many districts, as near Dynevor in Caermarthenshire, at Tideswell in Derbyshire, and near Settle in Yorkshire. The explanation most generally received supposes the water to fill cavities underground, from which the discharging channels are siphon-formed, so that at a particular moment the full cavity begins to be discharged and finally runs out, and the current then ceases till the space be again filled to the vertex of the siphon-formed arch.

In thus descending downwards and rising upwards through various mineral masses, springs become impregnated with gaseous, saline, earthy, or metallic admixtures—as carbonic acid gas, sulphuretted hydrogen gas, nitrogen, muriate of soda, sulphate of lime, carbonate of lime, silica, carbonate of iron, &c. [ARTESIAN WELL; WATERS, MINERAL.]

SPRINGS, MINERAL. [WATERS, MINERAL.]

SPY. In the discussion of this and many other questions of international law the terms Right, Law, Lawful, and others of the same class, must be understood in a different sense from their proper technical meaning. What writers on international law speak of as a Right is very often merely what appears fair, reasonable, or expedient to be done, or to be permitted. It is this reasonableness or expediency alone which is the foundation of those various usages which are recognised by independent civilised nations in their intercourse among one another, and constitute what is called the Law of Nations. Thus a person or a power is said to have a right according to the Law of Nations, which means that the usage of civilised nations permits the act, and this is the least objectionable sense in which the word Right is used.

No doubt, we believe, has ever been intimated by any writer of authority on International Law, as to the right of nations at war with each other to avail themselves of the service of spies, or secret emissaries, in carrying on their hostile operations; and still more expressly is the general right of employing spies conceded to every conductor of military operations; but it is equally admitted that spies when caught by the enemy may be hung, and such is their usual fate. Vattel says, "A man of honour always declines serving as a spy, as well from his reluctance to expose himself to this chance of an ignominious death, as because, moreover, the office cannot be performed without some degree of treachery." In ordinary cases, he adds, "the general must be left to procure spies in the best way he can, by tempting mercenary souls by rewards."

The employment of spies is conceived to be subject to certain limitations in respect to the manner of it and the object attempted to be gained by it. "We may lawfully endeavour," says Vattel, "to weaken the enemy by all possible means, provided they do not affect the common safety of human society, as do poison and assassination." Accordingly the proper business of a spy is merely to obtain intelligence, and such secret emissaries must not be employed to take the lives of any of the enemy, although that, done in another way, is commonly the main immediate object of the war. Yet it might be somewhat difficult to establish a clear distinction between what would be called an act of assassination by a spy, and many of those surprises of an enemy which, so far from being condemned or deemed dishonourable to the actors, have usually been admired. A distinction however has been taken; and it has been maintained that an officer or soldier cannot be treated as a spy if he had his uniform on when apprehended. See Martens 'Précis du Droit des Gens Modernes de l'Europe' (traduit de l'Allemand), Paris, 1831, liv. viii., ch. iv., § 274; where references are made to Bruckner, 'De Explorationibus et Exploratoribus,' Jen., 1700; to Hannov., 'Gel. Anzeigen,' 1751, pp. 383 et seq.; and, in regard to the celebrated case of André in the American war, to Martens, 'Erzählungen merkwürdiger Fälle,' i. 303; and to Kamptz, 'Beyträge zum Staats und Völkerrecht,' tom. 1., No. 3.

A question closely connected with the so-called lawfulness of employing spies, and indeed forming in one view a part of that question, is that of the lawfulness of soliciting the enemy's subjects to act as spies, or to betray him. Such measures, says Vattel, are practised in all wars, but they are not honourable nor compatible with the laws of a pure conscience. "If such practices," he concludes, "are at all excusable, it can be only in a very just war, and when the immediate object is to save our country when threatened with ruin by a lawless conqueror. On such an occasion (as it should seem) the guilt of the subject or general who should betray his sovereign when engaged in an evidently unjust cause would not be of so very odious a nature." But who ever heard of a war that was not thought by those engaged in it to be a just war on their own side and an unjust war on the part of their adversaries? So that this distinction settles nothing. It is held, however, to be perfectly allowable in every point of view merely to accept the offers of a traitor.

The proper question as to the so-called law of nations with regard to spies, is what practices are sanctioned by the general usage of independent civilised nations. Such practices as are now permitted by such usage constitute a part of this so-called international law. Those practices which are not generally permitted or acknowledged are not yet a part of such law. Persons who have occasion to write or think on this subject will find that much of the indistinctness and confusion observable in the treatises on the law of nations will be removed if they will first form for themselves a clear conception of the proper meaning of the word Law, and of the improper meanings which it has also acquired; and they will thus be enabled to give the necessary precision to those terms which are used so vaguely by writers on international law. [LAW; RIGHT.]

SQUADRON is supposed to be derived from "squadra" (Italian), which is itself corrupted from the Latin word "quadratum;" acies quadrata denoted a body of men drawn up in a square form. The term "escadron" occurs in Froissart's 'Chronicles,' and probably it was very early used in the French armies to designate a body of cavalry. It is generally used to designate a part of a fleet, or even of an army. Milton speaks of 'squadron'd' angels. Technically, however, it means the principal division of a regiment of cavalry, which is divided into two troops, each of which is commanded by its captain, who has under him a lieutenant and a cornet.

The strength of an army, with respect to cavalry, is usually expressed by the number of squadrons in the field, as it is with respect to infantry by the number of battalions.

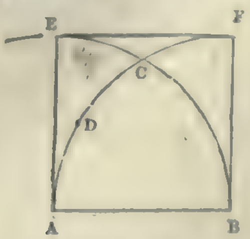
For the manner in which a regiment of cavalry is encamped, see ENCAMPMENT.

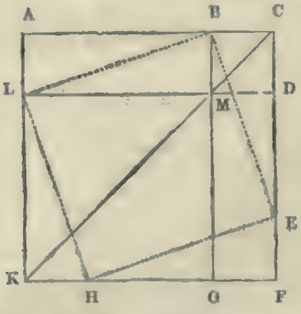
SQUARE. We believe that the old English meaning of this word had reference only to the corners of a figure, or at most to right-angled corners. The old word for any oblong, or rectangle, is a *four-square* figure; the carpenter's rule for drawing a right angle is called a T-square to this day. The French word *équerre* (anciently *esquerre*, originally derived, like the Italian *squadra*, from *quadratum*) is the immediate origin; and this (in French) means also an instrument for drawing a right angle. In Recorde's 'Ground of Arts,' the earliest English geometry extant, he calls what is now a square by the name of *square quadrate* (*square*, right-angled, *quadrate*, four-sided figure); and it is not until he is considerably advanced in his work that he seems to find out that he may drop the second word and retain the first only. There was still an incorrectness, for a square figure should have meant one having all its angles right angles; that is, what we now call a rectangle, whether its sides were equal or not. To complete the proof of connection between the square and the right-angled corner, we may mention that before now a right-angled *triangle* has been called a *square*. In or about 1613, Thomas Bedwell published a work, of which the title was '*Trigonum* Architectonicum, the Carpenter's Squire.'

In geometry, a square means a four-sided plane figure with all its sides equal, and all its angles right angles. In algebra, it signifies the number produced by multiplying a number by itself. The reason of the double meaning is obvious enough. [RECTANGLE.] A square of 7 units long contains 7×7 square units; so that the operation 7×7 is the arithmetic of finding the content of a square of 7 units in length and breadth. We have spoken, in the article just cited, of the confusion which is caused by this double use of the word square; and proposed to correct it by speaking of the square *on* a line in geometry, and the square *of* a number in algebra. It has been the fashion of late years to publish what are called *symbolical* editions of Euclid, in which AB^2 is made to stand for the square *on* the line AB, because a^2 stands for the square *of* the number a. The learner who uses this species of symbol will not, without great care, avoid false reasoning in making the connection between geometry and algebra.

A square is divided by its diagonal into two isosceles right-angled triangles: its diagonals are equal, and bisect each other at right angles. The easiest way of drawing a square is to describe two circles on the side A B, and bisecting A C in D, to make C E and C F equal to A D; the figure A E F B is then a square.

Of all similar figures, squares are those to the areas of which reasoning is most easily applied. If three similar figures be described on the sides of a right-angled triangle, the sum of those on the sides is equal to that on the hypothenuse. This proposition is learned with reference to squares [HYPOTHENUSE] long before it can be proved with reference to similar figures in general: the consequence is, that the general proposition is almost overlooked by the previous occurrence of the particular case. We have noted in the article just cited the Hindu proof of this celebrated case; the simplest properties of the square may be made to give a more easy proof, founded on the same principle; it being remembered that the first four propositions of the second book of Euclid do not require the last two of the first book. The proof is as follows:—Let A B, B C, be the sides of a right-angled triangle, and on their sum describe a square; make C E, F H, K L, each equal to A B. It is easily proved that L B E H is the square on the hypothenuse of the triangle; and it is made by subtracting four times the triangle from the whole square A F. But if four times the triangle be subtracted by taking away the rectangles A M and G D, we have (Euc., ii. 4) the sum of the squares on the sides, which is therefore the same as the square on the diagonal.





SQUARE ROOT, the name given to a number with reference to its square. Thus, 49 being the square of 7, 7 is the square root of 49. When an integer has no integer square root, it has no square root at all in finite terms: thus 2 has no square root. But since 1·4142136 multiplied by itself gives very nearly 2, or has a square very near to 2, it is customary to say that 1·4142136 is very nearly the square root of 2: more properly, the square root of something very near 2.

The extraction of the square root came into Europe with the Indian arithmetic, the method followed by Theon and other Greeks (which was substantially the same) having been forgotten. The earliest extensive treatise on the subject is that of P. A. Cataldi (Bologna, 1613), though the books of algebra and arithmetic had then been long in the habit of giving the rule. The process presently given for finding the square root of a number in a continued fraction was first given (in a less easy rule) by the same Cataldi, who was thus the first who used continued fractions. This fact was pointed out by M. Libri, before which Lord Brounker was generally considered as the first who used continued fractions.

The rule for the extraction of the square root is a tentative inverse process very much resembling division, and is contained under the general rule given in INVOLUTION AND EVOLUTION. The peculiar simplicity of this case, however, allows of a condensation of form, and makes the demonstration easy. The general rule just alluded to might be demonstrated on the same principle.

In order to turn the square of a into the square of $a+b$, we must add to the former $2ab+b^2$, or $(2a+b)b$. This follows from

$$(a+b)^2 = a^2 + 2ab + b^2.$$

An example will now show how the square root is extracted; first roughly, afterwards more skilfully in the choice of trials. Let the number be 104713. The square of 100 being 10000, which is much too small, we go on adding 100 to the square root, until no more hundreds can be added; all the while forming the squares by the rule, each square from the preceding. We then begin to add tens, forming the squares also, until the addition of one more ten would bring the square past 104713; we then add units, until either the square is exactly 104713, or the nearest to it. Or, instead of continual additions, we might subtract every number, as we get it, from 104713 until no more subtractions can be made. Both modes are exhibited in the following:—

$$\begin{array}{rr@{\qquad\qquad}r}
100^2 = & 10000 & 104713 \\
100\,(2 \times 100 + 100) = & \underline{30000} & \underline{10000} \\
200^2 = & 40000 & 94713\ a \\
100\,(2 \times 200 + 100) = & \underline{50000} & \underline{30000} \\
300^2 = & 90000 & 64713\ b \\
10\,(2 \times 300 + 10) = & \underline{6100} & \underline{50000} \\
310^2 = & 96100 & 14713\ c \\
10\,(2 \times 310 + 10) = & \underline{6300} & \underline{6100} \\
320^2 = & 102400 & 8613\ d \\
1\,(2 \times 320 + 1) = & \underline{641} & \underline{6300} \\
321^2 = & 103041 & 2313\ e \\
1\,(2 \times 321 + 1 = & \underline{643} & \underline{641} \\
322^2 = & 103684 & 1672\ f \\
1\,(2 \times 322 + 1) = & \underline{645} & \underline{643} \\
323^2 = & 104329 & 1029\ g \\
1\,(2 \times 323 + 1) = & \underline{647} & \underline{645} \\
324^2 = & 104976 & 384\ h
\end{array}$$

In the first column we feel our way, so to speak, by hundreds, by tens, and by units, up to the result that 323^2 is too small, and 324^2 too great; so that we see that 104713 has no square root. In the second column we go down from 104713, and subtracting the squares already formed in the first column, we come to the result that 104713 is 384 more than 323^2, but less than 324^2. The results of the second column are—

$$\begin{array}{r@{\qquad\qquad}r}
94713 = 104713 - 100^2 & 2313 = 104713 - 320^2 \\
64713 = 104713 - 200^2 & 1672 = 104713 - 321^2 \\
14713 = 104713 - 300^2 & 1029 = 104713 - 322^2 \\
8613 = 104713 - 310^2 & 384 = 104713 - 323^2
\end{array}$$

The best method of making the trials depends upon the following circumstances:—

1. A square number followed by an even number of ciphers, such as 16000000, is also a square number.

2. If $b\,(2a+b)$ is to be found as near as possible to R, and if $2a$ be considerable compared with b, the value of b is near to that given by $b \times 2a = \mathrm{R}$, or $b = \mathrm{R} \div 2a$.

Taking the number 104713, and parting it into periods of two numbers each, we have 10, 47, 13, and 9,00,00 is the highest square belonging to a simple unit followed by ciphers, which can be contained in it. Choose 300 for the first part of the root, and we have 14713 for the remainder. If b be the number of tens in the root, we have to make $10b\,(2 \times 300 + 10b)$ as near as we can to 14713, or $10b$ not being much compared with 600, we must try $10b \times 600 = 14713$, or $b = 14713 \div 6000$, whence 2 is the highest (perhaps too high, but that will be seen by the remainder). If $b=2$, $10b\,(600+10b)$ is 12400, which, subtracted from 14713, gives 2313. The part of the root now obtained is 320, and if c be the number of units, $c\,(2 \times 320 + c)$ must be made equal, or as near as can be, to 2313. Now c is very small compared with 640, and $c \times 640 = 2313$ shows that $c = 3$ at most, giving 3×643, or 1929, to be subtracted from 2313, which leaves 384. The process may be written thus:—

$$\begin{array}{rl}
 & 1\dot{0}4\dot{7}1\dot{3}\ (300 + 20 + 3 \\
 & \underline{90000} \\
600 & \big)\,14713 \\
20 & \big)\,\underline{12400} \\
640 & \big)\,2313 \\
3 & \big)\,\underline{1929} \\
 & 384
\end{array}$$

which, omitting superfluous ciphers, is the one commonly used. We do not intend to dwell on the common process, which is in all the books, but confine ourselves to the explanation, which is frequently omitted.

We now take a longer instance, at full length, followed by a statement of its results:—

```
             2̇90̇22̇52̇96̇ (10000
             100000000 \  7000
             ---------       30
      20000\ 190225296        6
       7000/ 189000000
             ---------
      34000\   1225296
         30/   1020900
               -------
      34060\    204396
          6/    204396
                ------
                     0
```

The following are the successive conclusions:—

$$290225296 - 10000^2 = 190225296$$
$$290225296 - 17000^2 = 1225296$$
$$290225296 - 17030^2 = 204396$$
$$290225296 - 17036^2 = 0$$

whence the given number is the square of 17036.

The rationale of the approximate extraction is as follows:—Suppose we wish to find, to four places of decimals, the square root of 1·74; that is, to find a fraction a, such that a^2 shall be less than 1·74, but that $(a+{\cdot}0001)^2$ shall be greater than 1·74. Give this fraction the denominator 1,00,00,00,00, which requires that its numerator shall be 1,74,00,00,00. This numerator is found, by the integer rule, to lie between 13190^2 and 13191^2, or 173976100 and 174002481. We have, then,—

$$(1{\cdot}3190)^2 = 1{\cdot}73976100$$
$$(1{\cdot}3191)^2 = 1{\cdot}74002481$$

which satisfy the conditions.

The common process of contraction, explained in books of arithmetic, has the following rule:—When the number of places in the divisor has so much increased as to exceed by 2 or more the number of places yet remaining to be found, instead of proceeding with the complete operation, leave the remainder unaugmented by any new period, strike one figure off the divisor, and proceed as in contracted division. If R be the remainder, a the part of the root found, b that remaining to be found, we have $b(2a+b)=\text{R}$. If a be very large compared with b, $2ab=\text{R}$ nearly, or $b=\text{R}\div 2a$ nearly; now $2a$ is the *divisor* in the rule. The fact is that b must lie between

$$\frac{\text{R}}{2a} \text{ and } \frac{\text{R}}{2a+\frac{\text{R}}{2a}}$$

Processes of this sort are often best shown, as to mere operation, by an instance in which the numerical computation gives no trouble. The following is a complete instance of the rule, exhibited in finding the square root of 4444·444444, &c.:—

```
            4̇44̇4̇·44̇44̇44̇, &c. (66·666666666667
            36
       126)844
            756
       1326)8844
             7956
       13326)88844
              79956
       133326)888844
               799956
       1333326)8888844
                7999956
       13333326)88888844
                 79999956
 13,3,3,3,3,3,2)8888888
                7999999
                 888889
                 800000
                  88889
                  80000
                   8889
                   8000
                    889
                    800
                     89
                     80
                      9
                      9
                      0
```

The given number is, in fact, 4444$\frac{4}{9}$, which is the square of 66$\frac{2}{3}$.

When R is the remainder, and a the part of the root found, the remaining part of the root is the continued fraction [FRACTIONS, CONTINUED.]

$$\frac{\text{R}}{2a+}\;\frac{\text{R}}{2a+}\;\frac{\text{R}}{2a+}\;\frac{\text{R}}{2a+}\;\&\text{c.}$$

But this is not a continued fraction of the most useful form, except when R=1. To reduce the remainder of a square root to a continued fraction in which all the numerators are units, proceed as follows (the process comes first and is followed by the explanation):—

To extract the square root of 21—

```
4 | 1  3  3  1  4  4 | 1
1 | 5  4  3  4  5  1 | 5
4 | 1  1  2  1  1  8 | 1
```

Let the number be N, the integer part of its root a, and write under one another in the first column, a, 1, a. Proceed to form the second, third, &c., columns, each from the preceding, in the following way:—If p, q, r, be in one column (found), and $p', q'\ r'$ in the next (to be found), then—

1. q' is $\dfrac{\text{N}-p^2}{q}$, and is always integer.
2. r' is the integer part of $\dfrac{a+p}{q'}$.
3. p' is $q'r'-p$.

Thus, for the second column we have $(21-16)\div 1$, or 5, for the second row; the integer of $(4+4)\div 5$, or 1, for the third row; and $1\times 5-4$, or 1, for the first row. In the third column we have $(21-1)\div 5$, or 4, for the second row; the integer of $(4+1)\div 4$, or 1, for the third row; and $1\times 4-1$, or 3, for the first row. In the fourth column we have $(21-9)\div 4$, or 3, for the second row; the integer of $(4+3)\div 3$, or 2, for the third row; and $2\times 3-3$, or 3, for the first row, and so on. This process must, after a time, begin to repeat itself; as soon as this happens, the last row shows the integer of the square root, and th succession of denominators of the continued fraction, which must be repeated as often as is necessary to give the required degree of accuracy. Thus,

$$\sqrt{21} = 4 + \frac{1}{1+}\;\frac{1}{1+}\;\frac{1}{2+}\;\frac{1}{1+}\;\frac{1}{1+}\;\frac{1}{8+}\;\frac{1}{1+}\;\frac{1}{1+}\;\frac{1}{2+}\;\frac{1}{1+}\;\frac{1}{1+},\ \&\text{c.}$$

If we proceed with the continued fraction as in the article cited, we have for the successive approximations to its value—

$$\frac{1}{1}\;\frac{1}{2}\;\frac{3}{5}\;\frac{4}{7}\;\frac{7}{12}\;\frac{60}{103}\;\frac{67}{115}\;\frac{127}{218}\;\frac{321}{551}\;\frac{448}{769}\;\frac{769}{1320},\ \&\text{c.}:$$

and $4\frac{769}{1320}$ only differs from $\sqrt{21}$ in the 8th decimal place. The use of this method is, not to extract the square root of any number which accidentally occurs, but to find convenient approximations, if possible, for square roots which frequently occur, and as to which it is therefore worth examination whether there may not be some common fraction which will serve the purpose as well as a decimal of considerable accuracy. For instance, we take $\sqrt{2}$ and $\sqrt{3}$, which represent the diagonals of a square and a cube having a unit for their sides. The processes are as follows:—

```
1 | 1  1, &c.        1 | 1  1  1  1, &c.
1 | 1  1, &c.        1 | 2  1  2  1, &c.
1 | 2  2, &c.        1 | 1  2  1  2, &c.
```

$$\sqrt{2} = 1 + \frac{1}{2+}\;\frac{1}{2+}\;\frac{1}{2+\&\text{c.}}\qquad \sqrt{3} = 1 + \frac{1}{1+}\;\frac{1}{2+}\;\frac{1}{1+}\;\frac{1}{2+},\ \&\text{c.}$$

The successive approximations to the fractions are—

$$\frac{1}{2}\;\frac{2}{5}\;\frac{5}{12}\;\frac{12}{29}\;\frac{29}{70}\;\frac{70}{169}\;\frac{169}{408}\;\frac{408}{985},\ \&\text{c.}$$

$$\frac{1}{1}\;\frac{2}{3}\;\frac{3}{4}\;\frac{8}{11}\;\frac{11}{15}\;\frac{30}{41}\;\frac{41}{56}\;\frac{112}{153}\;\frac{153}{209}\;\frac{418}{571}\;\frac{571}{780},\ \&\text{c.}$$

Thus we immediately see a convenient mode of finding the diagonal of a square, derived from

$$\sqrt{2} = 1 + \frac{29}{70} = \frac{99}{70} = \frac{100-1}{70},\ \text{nearly},$$

the excess of which above the truth is less than the 11830th part of the side. Thus, to find the diagonal of a square of 769·23 feet, we have

```
  76923
    769·23
  ----------
70)76153·77
    1087·911
```

which is too great by only about 6-hundredths of a foot.

The rule for extracting the square root of an algebraical quantity is very little needed, but is a remarkably good exercise in the operations of algebra. Arranging the square in powers of some one letter, the rule is identical with that for the square root of numbers in every point but this, that the new term is always found by dividing the *first term* of the remainder by the *first term* of the divisor. A couple of examples will suffice. Let it be required to find the square root of $1+2x+3x^2+4x^3+\ldots$.

$$\begin{array}{rl}
 & 1+2x+3x^2+4x^3+\ldots\ldots \qquad (1+x+x^2+x^3+\ldots \\
 & 1 \\ \hline
2+x) & 2x+3x^2+\ldots \\
 & 2x+x^2 \\ \hline
2+2x+x^2) & 2x^2+4x^3+5x^4+\ldots\ldots \\
 & 2x^2+2x^3+x^4 \\ \hline
2+2x+2x^2+x^3) & 2x^3+4x^4+6x^5+7x^6 \\
 & 2x^3+2x^4+2x^5+x^6 \\ \hline
 & 2x^4+4x^5+6x^6
\end{array}$$

Again, to find the square root of $1+x$:

$$\begin{array}{rl}
 & 1+x\left(1+\frac{x}{2}-\frac{x^2}{8}+\frac{x^3}{16}-\frac{5x^4}{128}+\ldots\right. \\
 & 1 \\ \hline
2+\frac{x}{2}) & x \\
 & x+\frac{x^2}{4} \\ \hline
2+x-\frac{x^2}{8}) & -\frac{x^2}{4} \\
 & -\frac{x^2}{4}-\frac{x^3}{8}+\frac{x^4}{64} \\ \hline
2+x-\frac{x^2}{4}+\frac{x^3}{16}) & \frac{x^3}{8}-\frac{x^4}{64} \\
 & \frac{x^3}{8}+\frac{x^4}{16}-\frac{x^5}{64}+\frac{x^6}{256} \\ \hline
 & -\frac{5x^4}{64}+\frac{x^5}{64}-\frac{x^6}{256}
\end{array}$$

SQUINTING (*Strabismus*). It is a condition essential to correct vision that the axes of both eyes correspond in direction, and be turned simultaneously towards the object we regard. Now to ensure the fulfilment of this condition, the orbital muscles (motores oculorum) are so supplied with nervous influence, that we cannot will the movement of one eye without the other being called into involuntary and harmonious action. There are some individuals, however, whose optic axes are not parallel, and whose eyes do not move in harmony with each other; such persons are said to squint, or to be affected with strabismus. Squinting may take place either upwards, downwards, inwards, or outwards, or in the intermediate directions; it may also be confined to one eye; or may affect both. As the inward and outward varieties of squint are by far the most common, we shall devote the following remarks to them alone.

Inward Squint, or Strabismus convergens, is met with in three distinct forms: 1, single convergent strabismus; 2, double convergent strabismus; and 3, alternating strabismus. In the first form of the affection one eye is habitually turned more or less inwards towards the inner angle of the orbit, whilst the other maintains its natural position, and is capable of being directed to any object that the individual wishes.

On closing the sound eye, the inverted one then becomes straight, and can be turned in every direction nearly to the same extent as the other; but as soon as it is again opened, the one affected with strabismus revolves inwards, and there remains; or if it do move along with the good eye, yet never so as to permit the two axes to be pointed at the same object. Double convergent strabismus differs from the preceding in its affecting both eyes; the axis of each eye is inclined unnaturally inwards, as if the person were regarding some object placed close to his face. On directing his attention to distant objects, the eyes do not become parallel, but the one least affected (for one is always more so than the other) becomes straight, whilst its fellow preserves its former position, or is turned more strongly inwards. With regard to the relative frequency of strabismus in one or in both eyes, it is said to affect most frequently one eye only, and this the left.

Alternating Strabismus differs from the ordinary form of squint, in its affecting both eyes *equally*, though never both at a time. An individual thus affected appears to use either eye indifferently; and the change of inversion from one eye to the other is a voluntary act, independent of the opening or closing of the eyelids.

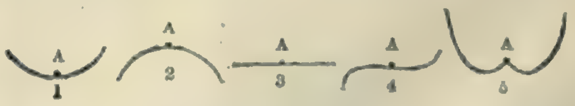
Outward Squint, or Strabismus divergens.—Nearly all that has been said in reference to convergent strabismus, may be applied, *mutatis mutandis*, to divergent squint. In this form of the affection, one eye is more or less everted, whilst the other is directed straight forwards; the patient is likewise incapable of directing both eyes inwards simultaneously. These cases we believe to be most frequently of the alternating kind; that is, the individual can employ either eye singly, and bring it into the central axis, but then its fellow becomes everted. It is a more rare affection than the former one, and the deformity arising from it is seldom so obvious. Whether we regard strabismus as affecting one eye or both, it is certain that the vision of the one most distorted is nearly always imperfect, and usually in a direct ratio with the degree of distortion. Now we know that if impressions on the two retinæ are dissimilar in force, the mind disregards the weaker, and takes cognizance only of the stronger; so that a person who squints badly generally sees objects with the sound eye only. If the sight of both eyes is equal or nearly so, double vision results whenever both are employed together, because the images of objects do not fall on corresponding portions of the two retinæ [SIGHT, DEFECTS OF]; and as the defect of sight is generally in a direct ratio with the degree of distortion, double vision is most frequently experienced in slight cases of squint.

Causes.—The inequality of power in the two eyes has been regarded by many as a cause of strabismus; the defective eye, it is said, "instead of being fixed on the object before it, is left to wander from the true axis of vision." When, however, we consider how numerous are the examples of unequal vision with the two eyes, yet unattended with squint, and the great and immediate improvement of sight which generally results from the operation for the removal of the defect, we may fairly question the influence of this cause in the production of strabismus. Among the remote causes which unquestionably contribute to this effect, may be enumerated convulsions, teething, the irritation arising from worms, ophthalmia, imitation, a habit of misdirecting the eyes, as by frequently looking at a mole on the nose, &c. The proximate cause resides in some affection of the muscles or nerves of the eyeball; either the balance of power between the former is lost, or the sympathy which exists naturally between the motor-oculi nerves of the two eyes is impaired.

Treatment.—This must depend upon whether the affection is of a temporary or permanent nature; in the former case it will be found to arise from some local irritation, and can be removed by suitable therapeutic remedies; in the latter, an operation will generally be required. Among the different other plans of treatment which occasionally have proved successful, we may enumerate binding up the sound eye; the employment of spectacles having glasses of different power; blinders projecting in front of the temples, with a view of attracting the eyes outwards; electricity, &c. The operation for the cure of strabismus is said to have suggested itself first to Dr. Stromeyer, from witnessing the success of tenotomy in contractions of the limbs. Dr. Dieffenbach of Berlin, however, was the first who had the boldness to carry it into practice on the living subject. The operation consists in dividing the muscle by which the distortion is produced, and thus allowing its antagonist to draw the eye again into the centre of the orbit. Although most cases of strabismus may be either completely cured or very much bettered by this operation, it is proper to remark that in some, neither this nor any other plan of treatment is of any avail. Provided, however, that the subjects to be operated on are judiciously selected, and the surgeon qualified for the task, there is no operation within the whole range of surgery which is more simple, more free from danger, or more satisfactory in its results, than the one in question.

STABLE AND UNSTABLE; STABILITY. A system is said to be stable when a slight disturbance of its actual condition would not produce a continually increasing effect, but one which finally ceases to increase, diminishes, becomes an effect of a contrary character, and so on, in an oscillatory manner. The ordinary vibration of a pendulum is an instance; the oscillation takes place about a stable position of equilibrium. We can give no instance of an unstable position; for by definition, such a thing is a mathematical fiction. Any disturbance, however slight, produces upon an unstable system an effect which continually increases: no unstable equilibrium therefore can exist a moment, for no system made by human hands can be placed with mathematical exactness in a given position. The pendulum has a position of equilibrium exactly opposite to that about which it can oscillate, but no nicety of adjustment will retain it in that position: it may appear to rest for a moment, but will almost instantly begin to fall.

The following curves or lines are all such that, supposing them to be rigid matter, a molecule placed at A would rest:—



In the first, a displacement to the right or left would produce nothing but oscillation, and the equilibrum is stable; in the second, neither displacement would be followed by any tendency to restoration, and the equilibrium is unstable; in the third, displacement would only be a removal to another position of rest, and the equilibrium is called indifferent. In the fourth, displacement to the right would be followed by restoration, but the velocity acquired in restoration would carry the molecule to the left, on which side there is no tendency to restoration: the equilibrium would then be permanently disturbed, and practically unstable; though it might be convenient to say that it is stable as to the disturbances to the right, and unstable as to those to the left. In the fifth, the equilibrium at A is unstable, but if a push, however slight, were given to the molecule, it would obviously, by reason of the two contiguous stable positions, oscillate about A, as if A were itself a stable position: and in the same manner a stable position, with an unstable one near to it, might, for a disturbance of sufficient magnitude, present the phenomena of an unstable position.

Now, suppose that the point A, instead of being a single molecule, is the centre of gravity of a system acted on by its own weight only; and let the curve drawn be the path of the centre of gravity, which, owing to the connection of the parts of the system with its supports, that centre is obliged to take. The phenomena of the single point still remain true: there is in every case a position of equilibrium when the system is placed in such a position that its centre of gravity is at A. In (1) the equilibrum is stable; in (2), unstable; in (3), indifferent; in (4), stable or unstable, according to the direction of disturbance; in (5), unstable, with results like those of stability. It is an error to state, as is frequently done, that there is no equilibrium in such a system except when its centre of gravity is highest or lowest; as is obvious from (3) and (4). The general proposition which *is* true is this—that a system acted on by its own weight is in equilibrium then, and then only, when its centre of gravity is placed at that point of its path which has its tangent parallel to the horizon, or perpendicular to the direction of gravity.

When a system is supported on three or more points, it is well known that there is no equilibrium unless the vertical passing through the centre of gravity cuts the polygon formed by joining these points. This must not be confounded, as is sometimes done, with a case of distinction between stable and unstable equilibrium; for it is a case of equilibrium or no equilibrium, according as the central vertical cuts or does not cut the base of the figure. Of course it is in the power of any one to say that stability means equilibration and instability non-equilibration; but such is not the technical use of these words in mechanics: stability and instability refer to equilibrium, stable equilibrium being that which would only be converted into oscillation by a disturbance, and unstable equilibrium that which would not be so converted.

Neither must the effects of friction or other resistances be confounded with those of a stable or unstable disposition. A ladder resting against horizontal ground and a vertical wall is maintained by friction; were it not for friction, there would not be rest in any position; and as it is, the angle which the ladder makes with the ground must not be too small. There is thus a set of positions, from the vertical one to a certain inclination, depending on the amount of friction, in all of which there is equilibrium; while in every other position there is no equilibrium. In no case must the words stability and instability be used in such manner as to confuse their popular with their technical sense.

Under Solar System is pointed out what is meant by the stability of that system. When a system has a motion of a permanent character, it is stable if a small disturbance only produce oscillations in that motion, or make permanent alterations of too slight a character to allow the subsequent mutual actions of the parts to destroy the permanent character of the motion. Suppose a material body, for instance, to revolve about an axis passing through the centre of gravity unacted on by any forces except the weight of its parts. If this axis be one of the principal axes, the rotation on it is permanent, that is, the axis of rotation will continue unaltered, even though that axis be not fixed. The rotation however, though permanent, is not *stable* about more than two out of the three principal axes. Let the first rotation be established about the axis which has the greatest moment of rotation, or the least, and if a slight displacement or disturbance be given, which has the effect of producing a little alteration of the axis of rotation, that alteration will not increase indefinitely, but will only occasion a perpetual transmission of the rotation from axis to axis, all the lines lying near to the principal axis first mentioned. But if that axis be chosen about which the moment of inertia is neither greatest nor least, any disturbance, however slight, will continually remove the axis of rotation farther and farther from the first axis, near which it will not return until it has made a circuit about one of the other two principal axes.

For the mathematical part of this subject, so far as we give it, see Virtual Velocities.

STADE DUTIES are so called from Stade, in the kingdom of Hanover, a town situated on the right bank of the Schwinge, three or four miles from where it falls into the Elbe, and 22 miles west by north from the city of Hamburg. The name *Brunshausen Tolls* is now more commonly used, from the village of Brunshausen, at the mouth of the Schwinge, where there is a custom-house and a royal guard-ship, and where the duties are collected which are levied on vessels and merchandise passing up the Elbe. The original duties, which were regulated by a treaty made in 1691, were light, but were gradually increased by the Hanoverian government till they amounted to about 40,000*l.* a-year. The duties levied were about ⅛ per cent. *ad valorem*, more on some articles and less on others. British vessels by a proclamation of Geo. II., December 1, 1736, were allowed under certain regulations to sail directly up to Hamburg, without coming to anchor at the mouth of the Schwinge, as other foreign vessels were obliged to do.

By a convention between the King of Hanover and the heads of the other Elbe-bordering states (Emperor of Austria, King of Prussia, King of Saxony, King of Denmark, Duke of Mecklenburg-Schwerin, Duke of Anhalt-Coethen, Duke of Anhalt-Dessau, Duke of Anhalt-Bernburg, Free and Hanseatic town of Lübeck, and Free and Hanseatic town of Hamburg), dated April 13, 1844, in conformity with articles 108 and 116 of Act of Congress of Vienna, of June 9, 1815, the Brunshausen Tolls were revised, regulated, and settled according to a Toll-Tariff agreed upon by the contracting parties.

These rates, by a treaty with Great Britain in July, 1844, were to continue in force till January 1, 1854. The treaty was then renewed, temporarily, while the question of the abolition of the duties was considered, as they were felt to be oppressive and unjust, nothing being done to benefit the navigation in return for them. At length a compensation of 3,000,000*l.* was offered, of which Hamburg, which would derive the greatest benefit, was to pay one-third; Great Britain 1,125,206*l.*, and all the other commercial states of Europe with the United States of America the remainder, in proportion to their commerce. This has been agreed to, but the ratification has not yet been completed.

STA'DIUM (*ὁ στάδιος* and *τὸ στάδιον*), the principal Greek measure of length, was equal to 600 Greek or 625 Roman feet, that is, to 606 feet 9 inches English. The Roman mile contained 8 stadia. The Roman writers often measure by stadia, chiefly in geographical and astronomical measurements. (Herod., ii. 149; Plin., 'Hist. Nat.,' ii., 23 or 21; Columell., 'Re. Rust.,' v. 1; Strabo, vii., p. 497.)

The standard length of this measure was the distance between the pillars at the two ends of the foot-race course at Olympia, which was itself called *stadium*, from its length, and this standard prevailed throughout Greece. Some writers have attempted to show that there were other stadia in use in Greece besides the Olympic. The only passages in which anything of the kind seems to be stated are one in Censorinus ('De Die Natali,' c. 13), which, as far as it can be understood, evidently contains some mistake; and another which is quoted by Aulus Gellius (i. 1) from Plutarch, but which speaks of the race-courses called stadia, not of the stadium as a measure.

The principal argument for a variety of stadia is that of Major Rennell ('Geog. of Herod.,' s. 2); namely, that when ancient authors have stated the distances between known places, and a comparison is made between their statements and the actual distances, the distances stated by them are invariably found to be too great, never too small. Hence the conclusion is drawn that they used an itinerary stade shorter than the Olympic. If so, it is strange that the very writers who have left us these statements of distances have not said a word about the itinerary stade which they are supposed to have used, while several of them often speak of the Olympic stade as containing 600 Greek feet. But there is a very simple explanation of the difficulty, which is given by Ukert, in his 'Geographie der Griechen und Römer' (i., ii., p. 56, &c.). The common Greek method of reckoning distances, both by sea and land, was by computation, not by measurement. A journey or voyage took a certain number of days, and this number was reduced to stadia, by allowing a certain number of stadia to each day's journey. The number of stadia so allowed was computed on the supposition that circumstances were favourable to the traveller's progress; and therefore every impediment, such as wind, tide, currents, windings of the coast, a heavily laden or badly sailing ship, or any deviation from the shortest track by sea, and the corresponding hindrances by land, would all tend to increase the number of days which the journey took, and consequently the number of stadia which the distance was computed to contain. These circumstances, together with the fact that the Greek writers are by no means agreed as to the number of stadia contained in a day's journey, and other sources of inaccuracy which we know to have existed, furnish a satisfactory explanation of the discrepancies which we find in their statements of distances, both when compared with one another, and when compared with the actual fact, without there being any occasion to resort to the supposition of a stade different from the Olympic. Colonel Leake 'On the Stade as a Linear Measure' ('Journal of the Royal Geographical Society of London,' vol. ix., 1839), has also come to the conclusion "that the stade, as a linear measure, had but one standard, namely, the length of the foot-race, or interval between the *ἀφετήρια* and *καμπτῆρ* in all the stadia of Greece, and which is very clearly defined as having contained 600 Greek feet."

When we come however to writers as late as the 3rd century of the Christian era, we do find stadia of different lengths. Of these the chief are those of 7 and 7½ to the Roman mile. (Wurm, 'De Pond.,' &c., § 58.)

The following table, from the Appendix to Hussey's 'Ancient

Weights and Money,' represents the supposed varieties of the Greek stadium :—

	Yds.	Ft.	Inch.
Stade assigned to Aristotle's measurement of the earth's surface	109	1	2·26992
Mean geographical stade, computed by Major Rennell	108	1	6
Olympic stade	202	0	9
Stade of 7½ to the Roman mile	215	2	2·4
Stade of 7 to the Roman mile	231	0	5·124

2. The race-course for foot-races at Olympia was called stadium, as above mentioned, and the same name was applied to all other such courses.

The stadium consisted of a flat area, surrounded by raised seats, and was made either in a spot which had by nature the required shape, or in the side of a hill, or on a plain. In the last two cases the stadium was constructed by forming a mound of earth of the proper shape, and covering it with stone or marble for the seats. The second of these three forms was the most common. Of the third we have a fine example in the Panathenaic Stadium at Athens. The area of the stadium was oblong, terminating at one end in a semicircle. At the other end it was bounded by a wall, at the two extremities of which were the entrances, one on each side of the stadium. Here was the starting-place (*ἄφεσις*, *γραμμή*, *ὕσπληξ*, or *βαλβίς*), marked by a square pillar in the middle of the breadth of the area. Another such pillar was placed at the other end of the course, at the distance of a stadium from the former, and at or near the centre of the semicircular end of the area. This pillar marked the termination of the simple foot-race [OLYMPIAN GAMES], but in the Diaulus the runners turned round it and went back to the starting-place; in the Dolichus they turned round both pillars several times, according to the number of stadia of which the course consisted. The end of the course was called *τέρμα*, *βατήρ*, *τέλος*, *καμπτήρ* and *νύσσα*. Halfway between these pillars stood a third. On the pillar at the starting-place was inscribed the word *ἀρίστευε* (*excel*); on the middle one, *σπεῦδε* (*hasten*); on the one at the goal, *κάμψον* (*turn*). The semicircular end of the area (*σφενδόνη*) was thus not used in the foot-race. Here probably the other gymnastic contests took place; for though the stadium was originally intended only for the foot-race, yet as the other contests came to be added to the games, they also took place in the stadium, except the horse-races, for which a separate course was set apart, shaped like the stadium, but larger: this was called *ἱππόδρομος*.

Among the seats which surrounded the area, a conspicuous place, opposite to the goal, was set apart for the three Hellanodicae, who decided the contests, and who entered the stadium by a secret passage. Opposite to them on the other side of the stadium, was an altar, on which the priestesses of Demeter Chamyne sat to view the games. The area was ornamented with several altars and statues.

The position of the stadium was sometimes, but not always, in connection with the gymnasium.

Under the Romans many of the Grecian stadia were modified so as to resemble the amphitheatre.

There still exist considerable ruins of stadia: among the most remarkable of which are those at Delphi, Athens, Messene, Ephesus, and Laodicea.

(Pausanias, ii. 27, 6; vi. 20, 5, 6; ix. 23, 1; Müller's *Archäologie der Kunst*, sec. 290; Krause, *Die Gymnastik und Agonistik der Hellenen*, i., p. 131, &c.)

STADTHOLDER (*Statthalter* in German, *Stadhouder* in Dutch) means lieutenant or governor. The appellative Statthalter is used in the cantons of German Switzerland, to denote the civil officer who is next to the landamman or chief magistrate. In the federal republic of the Seven United Provinces of the Netherlands, the stadhouder was himself the first magistrate or president of the Union. When several of the towns of Holland revolted against the tyranny of the Duke of Alba, the lieutenant of King Philip of Spain, they chose for their governor William, prince of Orange, swearing allegiance to him as the king's stadhouder, thus implying that they had revolted against the Duke of Alba and not against King Philip. But it was not until after the death of William, in 1584, that the three united provinces of Holland, Zealand, and Utrecht agreed to have one stadhouder in common, and appointed to that office Maurice of Nassau, son of the deceased William. (Puffendorf.) From that time the stadhoudership continued in the house of Nassau till the death of William III. in 1702, when the male line of William I. becoming extinct, the office remained vacant, and was considered as tacitly abolished. But in 1747, after a struggle between the republican and the Orange parties, the latter, having triumphed, proclaimed William IV., of a collateral branch of the Nassau family, hereditary stadhouder of the Seven United Provinces. His son William V. was expelled by the French in 1795, and resigned the stadhoudership by treaty with France in 1802, since which the office has not been revived, the republic of the Netherlands having been transformed into a kingdom.

STAFF, in Music. The five parallel lines and the four spaces between the lines, on which notes and other musical characters are placed, are, collectively, called the *Staff*.

STAFF, MILITARY. In the British empire this consists, under the sovereign and the general commanding-in-chief, of those general, field, and regimental officers to whom is confided the care of providing the means of rendering the military force of the nation efficient, of maintaining discipline in the army, and regulating the duties in every branch of the service.

Besides the commander-in-chief, his military secretaries and aides-de-camp, the general staff consists of the adjutant and quartermaster-generals, with their respective deputies, assistants, and deputy-assistants, a deputy, assistant, and deputy assistant adjutant-general for the royal artillery, and a deputy and assistant adjutant general for the royal engineers; the director-general of the medical department, and the chaplain-general of the forces. The staff of the ordnance department consisted formerly of the master-general and lieutenant general, with their deputies and assistants: the inspector-general of fortifications, and the director-general of artillery, &c. The duties connected with the Ordnance having been transferred to the War Department, the office of master-general has been abolished, and the staff made a part of the War Office. The head-quarters for the general staff are in London. There are also, for the several military districts into which Great Britain is divided, inspecting field-officers, assistant adjutants-general, and majors of brigade, together with the officers attached to the recruiting service. The head-quarters for Scotland are at Edinburgh. For Ireland, besides the lord-lieutenant and his aides-de-camp, the chiefs of the staff consist of a deputy-adjutant and a deputy-quartermaster-general, with their assistants. Their head-quarters are at Dublin; and there are, besides, the several officers for the military districts of that part of the empire. Lastly, in each of the colonies there is a staff graduated in accordance with the general staff of the army, and consisting of the general commanding, his aides-de-camp, military secretaries, and majors of brigade, an inspecting field-officer, a deputy-adjutant, and a deputy-quartermaster-general.

The adjutant-general of the army is charged with the duty of recruiting, clothing, and arming the troops, superintending their discipline, granting leave of absence, and discharging the men when the period of their service is expired. To the quartermaster-general is confided the duty of regulating the marches of the troops, providing the supplies of provisions, and assigning the quarters, or places of encampment.

All military commanders of territories or of bodies of troops in Great Britain, Ireland, or in foreign stations, transmit periodically to the adjutant-general of the army circumstantial accounts of the state of the territory and of the troops which they command; and the reports are regularly submitted to the general commanding-in-chief.

The staff of a regiment consists of the adjutant, quartermaster, paymaster, chaplain, and surgeon.

The first establishment of a permanent military staff (état majeur, as it was called) was made in France in 1783, about the conclusion of the Revolutionary war between Great Britain and the United States of America. The officers who held the highest rank in it were considered as assistant-quartermaster-generals, and their deputies as captains. The first duties consisted in collecting the reports, the orders, and instructions which had formerly passed between the generals of the French armies and the minister of war, together with the plans of the ground on which the most important actions had taken place; and from these documents it was endeavoured to acquire a knowledge of the causes of success or defeat as far as these depended on the dispositions of the troops and the nature of the ground. The persons who were allowed to enter the department of the état majeur were such as, to a knowledge of the general theory of military tactics, added that of topographical surveying, and who were skilful in the art of representing on a plan the features of ground so as to present to the eye at once a view of its capabilities as a military position, and of the facilities which it might afford for the march of troops with their artillery and stores.

About the year 1800 the British government first formed a particular school for the purpose of instructing officers in the art of surveying ground in connection with that part of tactics which relates to the choice of routes and of advantageous positions for troops. These officers were independent of the master-general of the ordnance, and served under the orders of the quartermaster-general or adjutant-general; they were called staff-officers, and were selected from the cavalry or infantry after having done duty with a regiment at least four years. They were first employed in Egypt, where they rendered considerable service; and the school was afterwards united to the Royal Military College, which had been then recently instituted for the instruction of cadets who were to serve in the cavalry or the infantry of the line. At that institution a limited number of officers, under the name of the senior department, continue to be instructed in the duties of the staff, and in the sciences connected with the military art. All officers are now obliged to pass an examination before they can be employed on the staff of the army, and they may either enter the Staff College at Sandhurst by a competitive examination, and remain there for two years, or may qualify for the staff by passing the same examination as is required of the officers at Sandhurst at the end of their course of study.

During the war in Spain, from 1808 to 1813, the staff-officers were constantly employed, previously to a march or a retreat, in surveying the country at least one day's journey in front of the army. After the death of the Duke of York, the staff corps ceased to be kept up, and for several years it was reduced to a single company, which was charged with the duty of repairing the military canal at Hythe. This company was afterwards incorporated with the corps of sappers and miners.

The duties of officers belonging to the quartermaster-general's staff, though in certain respects similar, are different from those of the military engineers; the latter are employed in the construction of permanent fortifications, batteries, and field-works; while the former survey ground in order to discover roads, or sites for military positions, for fields of battle, or quarters for the troops. The education of a staff-officer is such as may qualify him for appreciating the military character of ground: for this purpose he learns to trace the directions of roads and the courses of rivers or streams; and in mountainous countries to distinguish the principal chains from their ramifications, to examine the entrances of gorges, and to determine the heights of eminences or the depths of ravines. He has, besides, to acquire a facility in determining or estimating the resources of a district with respect to the means it affords of supplying provisions or quarters for the troops. [RECONNAISSANCE.]

The staff-officer ought also to know how to correct the illusions to which the eye is subject in examining ground, from the different states of the air, and the number and nature of the objects which may intervene between himself and those whose positions are required. He ought to be able to estimate the number of men whom a visible tract of ground can contain, and to form a judgment concerning the dispositions and stratagems which it may permit an army to put in practice.

STAGE CARRIAGE. Although the law regards differently a *stage* carriage and a *hackney* carriage, we may conveniently treat of both here. The former group comprises *stage coaches* and *omnibuses*, for the use of which passengers pay at the rate of so much per journey; the latter group comprises *hackney couches* and *cabs*, for which passengers pay either at so much per mile or so much per quarter of an hour. As to coaches generally, it needs simply to be observed here, that they were introduced into England about 1570, and that a long time elapsed before their use became customary among wealthy persons.

Hackney Carriages.—The derivation of the word Hackney, as applied to a class of public conveyances, has occasioned much speculation. The suburb of *Hackney;* the French *Hacquenée* and *Haque*, both derived from the Latin, *equus*, a horse; and the Anglo-Saxon equivalent for "neighing" have been severally proposed as the probable origin for the name. However this may be, it is sufficiently evident that the term *hackney* was first applied to horses let for hire, and then, by a very natural transition, extended to coaches, and subsequently to sedan-chairs, employed in a similar way.

Hackney carriages appear to have originated in London. It was in 1625 that they began to ply in London streets, or rather at the inns, to be called for as they were wanted; and they were at this time only twenty in number. In 1634 sedan-chairs appear, for the first time, to have entered into competition with hackney-coaches, the sole privilege being granted in that year to Sir Sanders Duncomb. In the following year an attempt was made to check the increasing annoyance occasioned by the "general and promiscuous use of coaches" by a proclamation from the king (Charles I.) that no hackney or hired coach should be used in London, Westminster, or the suburbs, unless it were engaged to travel at least three miles out of the same; and that every hackney-coach owner should constantly maintain four able horses for the royal service when required. Finding it impossible to prevent the use of so great a convenience, a commission was issued to the master of the horse in 1637 to grant licences to fifty hackney-coachmen in and about London and Westminster, and as many others as might be needful in other places in England, each coachman being allowed to keep not more than twelve horses. In 1652 the number of hackney-coaches daily plying in the streets was limited to 200; in 1654 it was increased to 300, allowing however only 600 horses; and an increase was at different times allowed till 1771, when the number of coaches was further increased to 1000. Notwithstanding this steady increase in the use of hackney-coaches, they were long assailed as public nuisances.

The first hackney-coach *stand* was established in 1634, by one Captain Baily, near the May-pole in the Strand. Even so late as 1660 Charles II. issued a proclamation against hackney-coaches standing in the streets to be hired. The monopoly long enjoyed by the London hackney-coachmen produced great indifference to the increasing wants of the community; even down to the year 1823, while that monopoly was undisturbed, hackney-coaches appear to have sunk lower and lower in the scale of efficiency.

While this was the state of things in London, a lighter kind of vehicle, drawn by one horse, called *cabriolets de place*, had been brought into extensive use in Paris. But it was not till 1823, and then with great difficulty, that licences were obtained for eight cabriolets to be started at fares one-third lower than those of hackney-coaches. The new vehicle was a hooded chaise, drawn by one horse, and carrying only one passenger besides the driver, who sat in the cabriolet (or, as more commonly called for brevity, the *cab*), with his fare. An improved build was soon introduced, by which room was provided for a second passenger, and the driver was separated from the fare. With the rapid extension of this lighter class of vehicles, numerous varieties of construction have been introduced, in which comfortable and safe accommodation, with complete shelter from the weather and separation from the driver, is provided for two, three, or four persons. The name *cab* is still commonly applied to all hackney-carriages drawn by one horse, whether on two or four wheels. During the first few years of the employment of such carriages their number was restricted to 65, while the number of coach-licences was increased to 1200; but in 1832 all restriction as to the number of hackney carriages was removed.

Since the year 1822 hackney carriage-drivers have been required to deposit any articles which may be accidentally left in their vehicles with the registrar of licences, to whom the owners of the lost property may apply for its restoration. The property thus recovered has often exceeded 10,000*l.* in a single year. To lessen the risk in reference to one important department of hackney carriage business, the railway companies which have termini in London enter into arrangements by which a limited number of carriages, driven only by men of well attested respectability, are allowed to stand within their stations, to convey passengers to their respective destinations, under a system of supervision so strict, that any case of misconduct or overcharge is almost certain to be brought home to the guilty party.

The hackney carriages of the metropolis are now regulated as to vehicles, drivers, and fares by the Act 16 & 17 Vict. c. 33, (1853). Every owner of a stage-carriage must be licensed. On applying to the Commissioners of Police for a licence, his vehicle is to be inspected; if it be approved on inspection, the Commissioners grant a certificate, stating how many persons the vehicle is permitted to carry. On the presentation of this certificate, the Board of Inland Revenue grants a licence. The police commissioners are empowered, at any time deemed by them proper, to order an inspection of metropolitan stage and hackney-carriages and horses; if any are found in improper condition, notice thereof is sent to the proprietor; if he neglect to attend to this warning, the commissioners may suspend his licence for a stated time, and take away his Stamp Office plate until after the expiration of that time. The fares for hackney-carriages are fixed at 6*d.* for every mile or fraction of a mile, or 2*s.* per hour. Back fares are disallowed; but 6*d.* per quarter of an hour is allowed for detention. Each hackney-carriage is to be provided with a table of fares, and each driver with a book of fares, which he is to produce when required. The driver must not refuse to carry a fare, if the distance be within six miles or the time within an hour; beyond these limits he may exercise an option. When hired by time, the driver is not bound to go more than four miles an hour, unless paid 6*d.* per mile extra. The driver is to give a ticket to his fare, inscribed with the Stamp Office number of the carriage. The carriage must contain, in writing, a notification of the number of persons it may carry at once. A reasonable quantity of luggage is to be taken free of charge. Property left in carriages is to be accounted for, by the driver, under certain regulations. Lamps are to be lighted in or on the carriages at night. The police are to have control over all the coach-stands. In the cases where a hackney-carriage is drawn by more than one horse, an addition of one-third may be made to the fare. The driver may refuse to charge by time instead of distance, between eight in the evening and six in the morning. If more than two persons ride in a hackney carriage, 6*d.* for each is charged (over any distance) beyond the regular fare.—All these provisions are enforced by fine or imprisonment.

The above act related chiefly to hackney-carriages in connection with the public. Another, relating to their connection with the revenue, was passed in the same year (16 & 17 Vict. c. 127). The old duties (5*l.* for a licence, and 10*s.* per week) were repealed, and lower duties imposed. The licence for every hackney-carriage is to be 2*l.*, and the duty is to be 6*s.* or 7*s.*, according as the carriage is to be worked six or seven days in a week. Every licence is for one year only, and is to be renewed annually. The number-plate is proof of the licence. Drivers are entitled to charge 1*s.* per mile instead of 6*d.* for any portion of their route beyond four miles from Charing Cross; provided the carriage is *discharged* beyond that limit. A proprietor must not withdraw his hackney-carriage from plying, beyond one day at a time, without giving notice of his intention to that effect.

We must here state that hackney carriages, as regulated by law, comprise only those which work within the police limits of the metropolis. Beyond those limits, the owners have to pay *post-horse duty* [POSTING], and possibly some local tax imposed by municipal authorities; but none of the duties mentioned in this article. The sum contributed to the national revenue by the London cabs (for in the middle of 1860 there was only *one* pair-horse hackney-coach left) is considerable. The duty of a shilling a day brings in about 80,000*l.* or 85,000*l.* per annum; while the cab licence, and the drivers' and watermen's licences, raise this to about 4000*l.* more. There were rather over 5100 London cabs in the middle of 1860. The drivers are more numerous than the cabs; for there are often a day driver and a night driver for the same vehicle. The six-day cabs, which do not run on Sundays, bear for distinction numbers expressed by five figures, beginning with 10,000. Of the sum realised by the government from the metropolitan cabs, about 13,000*l.* is annually handed over to the Commissioners of Police, to defray the expenses of supervision, watermen, coach-stands, &c. It is computed that seven horses are on an average kept for three cabs. Some of the cab-masters own above fifty vehicles each; most of them own a few only: and in certain cases the cabman is the owner of the vehicle which he drives. The patent or 'Hansom' cabs, peculiar for their construction and their high speed, are well-horsed; and there is observable a gradual improvement in the general condition of the horses employed in the London cabs.

In Paris, the hackney carriages are under strict regulation. The general custom has been to charge so much for a *course*, or journey, whether long or short, provided it be within the limits of Paris. This charge used to be one franc; but practically, a fee to the driver raised it to a few sous more. A few years ago this system was changed; every vehicle was provided by the authorities with a timepiece or watch, and fares were charged by the hour. For some reason this system was abandoned after a trial, and the old method of paying for the course resumed. The pernicious custom of allowing the driver to demand a fee or "pour boire," without defining its amount, continues.

Stage Carriages.—We have next to notice those public carriages which run regular stages or routes, and which charge by the journey, not by the mile or the hour.

Stage-coaches were first used in England soon after the introduction of hired carriages. In Scotland, in 1678, Provost Campbell established a coach to run from Glasgow to Edinburgh, "drawn by sax able horses, to leave Edinboro' ilk Monday morning, and return again (God willing) ilk Saturday night." The first mail coach travelled from London to Edinburgh about 1785, and to Glasgow in 1788. Springs were the first means towards better travelling; since their invention, the increased speed and better appointment of English stage-coaches have been caused by the improvement of roads, in conjunction with the great demand for rapid travelling. In this country the best stage-coaches were very perfect machines, and the arrangements by which they were conducted were well-planned, but some deterioration has taken place since their very general displacement by railways. The expense of *horsing* a four-horse coach, running at the speed of from nine to ten miles an hour was reckoned at 3*l.* a double mile for 28 days (a lunar month); so that a person horsing ten miles of a coach passing backwards and forwards each day, required to earn or receive by way of remuneration 13 times 30*l.* or 390*l.* a year for his work. Mails are exempt from turnpike tolls, but a tax is paid for them to the government, and mileage to the contractor for the use of the coach. The Post-office allows them a certain sum, determined by circumstances, per mile for carrying the letters; in consideration of this, it claims a right to limit their number of passengers, and regulate their speed and time of starting: the guard is the servant of the Post-office.

Short-stage-coaches, plying in the neighbourhood of towns, have been nearly superseded by omnibuses.

Until about the year 1830, in the metropolis a few slow and unpunctual stages were the only means of transit provided for the citizens to convey them to their suburban residences. A little earlier, only one stage plied from Paddington to the Bank; and this single vehicle, going in the morning and returning at night, was not always full. Its fares were two shillings inside, and eighteen-pence outside. The old stage-coaches could only carry four, or at most six, inside passengers; and when an attempt was made, about the year 1800, to introduce a more commodious kind of vehicle, resembling an omnibus, the project failed, in consequence of a general prejudice against the hearse-like appearance of the carriage. The long-bodied carriage then tried was drawn by four horses, and had six wheels. When re-introduced from Paris, the omnibus had four wheels, but was much longer and heavier than at present, and was drawn by three horses abreast. The first successful omnibus in London was started by a coach-builder named Shillibeer, in 1829, to run between Greenwich and Charing-Cross, at fares considerably less than those of the old short stages; in addition to which advantage, the greater part of the passengers were sheltered from the weather. Success in the first experiment led Shillibeer to establish omnibuses between Paddington and the Bank. After opposing the innovation most violently for a time, the old coach-proprietors followed his example, started omnibuses of their own, and by combined opposition succeeded in driving him entirely off the road; not, however, before the new system of travelling was fully established.

A few notices concerning the omnibus system of the present day may be added; but we must first speak of the legislation on the subject of stage-carriages.

In 1799 the Act of Parliament was passed (19 Geo. III., c. 51) which first imposed a duty on hired carriages of any description. This duty has at times been variously regulated. By an Act passed in 1833, the duty on stage-coaches was made to depend on the number of miles such carriage is authorised by the licence to travel in the day, week, or month, as the case may be. This duty might be compounded for. Every stage-carriage is to have a numbered plate affixed to it; a licence is necessary for every pair of plates, and the number of passengers each carriage is allowed to carry is stated in the licence. These regulations are applicable to all such carriages throughout the country, and include the more recently introduced *omnibus*, a word in no way recognised by the legislature. The conduct of the stage-carriages which are employed in London and within ten miles of the General Post-office, is further regulated by an Act passed in 1838, in which they are directed to be called "metropolitan stage-carriages," and by which, besides the rules applicable by previous acts to these conveyances as stage-carriages, other enactments are made as to the Stamp-Office plates, &c. It also empowers the Secretary of State to appoint a Registrar of Metropolitan Stage-Carriages, whose duty it is to issue the licence which the Commissioners of Stamps are authorised to grant to drivers and conductors. These licences the registrar may grant to any person above 16 years of age who can produce certificates of his ability to drive, and of good character. The licence is renewable yearly, and with it is given an abstract of the laws and penalties to which the receiver is amenable, and a numbered ticket, the latter of which he is to wear conspicuously on his person, and not to transfer or lend. The duty is calculated in the proportion of so much per mile according to the number of passengers the carriage may be licensed to carry.

Another regulative Act was passed in 1843. Proprietors are, as before, to fix their own fares; but the list of fares is to be painted within-side the coach or omnibus. A further Act, passed in 1855, contained two or three clauses relating to stage-carriages. The mileage duty is reduced from 1½*d.* to 1*d.* per mile. The charge for a supplementary licence is reduced from 5*s.* to 1*s.* On the other hand, the liberty to compound for stage-carriage duties is withdrawn.

In 1836, a joint-stock association called the "London Conveyance Company" was established, which proposed to run omnibuses along the principal lines of traffic, starting at short and regular intervals, and conducted by men of sober and respectable character. The result of this experiment was so successful, that other owners formed themselves into bodies of similar character. In the course of a few years the association system was almost universally adopted in the metropolis. For some years the traffic from Paddington to the Bank through Holborn was managed by the London Conveyance Company, with more than eighty omnibuses, and not less than a thousand horses. Each of the omnibuses performed upon an average six double journeys per day, and required at least ten horses to work it, independent of casualties. These horses were selected for strength and activity, and an experienced veterinary surgeon, with a staff of assistants and farriers, was employed to attend to them. The annual receipts of this company alone were roughly estimated at 80,000*l.* to 100,000*l.* About the year 1844 it was found that, out of 1400 metropolitan omnibuses, 200 were engaged on various routes to Paddington. In 1855 a "London General Omnibus Company" was established. It was of French origin, as a *Société en Commandite*, but was afterwards transformed into an English Company with limited liability. A capital was raised by shares; and the company proceeded, not to establish new omnibuses and omnibus routes, but to purchase those already existing. The sets of omnibuses known as the "Wellington," "Atlas," "Waterloo," "Favourite," &c., were one by one bought up. On an average the company purchased eleven horses with each omnibus. In order to propitiate the public the company promised new and superior vehicles. They offered a prize of 100*l.* for a design for an improved omnibus; but though the prize was awarded, the company have not adopted that or any other particular model in the build of their omnibuses. The operations gradually extended until the company became possessed of more than 600 omnibuses: each omnibus, with its stud of horses, harness, and "goodwill" of the business already established, cost on an average about 700*l.* The horses exceed 6000 in number. It has been found that these metropolitan omnibuses, one with another, run more than 20,000 miles a year each. In renewing the stock the average expenditure has been about 120*l.* per omnibus, 30*l.* per horse, and 12*l.* harness. Each horse, under average prices, costs 26*s.* per week for food, litter, medicine, shoeing, attendance, &c. The "wear and tear" of omnibus and harness per week is about 24*s.* The horses run about 12 miles per day each on an average.

The transactions of this company during the year 1860 present a strange result in a financial point of view: 40,000,000 passengers had been conveyed, and had paid about 589,000*l.* to the company for that service; but the expense incurred in rendering the service was 591,000*l.*, showing a small but actual loss on the whole year's operations, and leaving no dividend whatever for the invested capital. The receipts show an average of about 3½*d.* per passenger.

The omnibuses in Glasgow, Liverpool, Manchester, and several other towns, are in most respects superior to those of London. Projects have been formed for running omnibuses on tramways in the public streets; this plan was commenced at Birkenhead in 1860.

The mileage duty paid to the government for the metropolitan omnibuses amounts to about 70,000*l.* a year; to which is added about 15,000*l.* a year for stamp-duty, and drivers' and conductors' licences. Stage-coaches and omnibuses are not so severely taxed in other parts of the kingdom. In Ireland the road traffic is mostly conducted by means of Bianconi's stage cars—a remarkable example of successful and effective private enterprise.

STAINING. [DYEING; GLASS MANUFACTURE; PAPER HANGING.]

STAIRCASE. This is an indispensable part of the interior of buildings which consist of more than a ground-floor, and stairs of some sort must have always been employed wherever there were upper rooms, and even to obtain access to the terraced roofs which are used in the East. But we are altogether ignorant of the character of ancient staircases. Vitruvius—who touches upon so many matters that are very remotely connected with his subject—gives no information about staircases; neither has much light been thrown upon the subject by the discoveries of Pompeii. Scarcely any indications even of upper floors to the houses have there been found, and what few traces of staircases, or rather of stairs, remain, show them to have been exceedingly incommodious, fitted only for obtaining access to an upper loft, or to the roof, and not at all adapted for constant communication between dwelling apartments on different floors. It may, therefore, very safely be taken for granted—at least until some direct evidence to the contrary shall be found—that the houses of the ancients were in this, as well as in many other respects, greatly inferior to our own, and had nothing whatever corresponding to the modern staircase. Nearly the same may be said with respect to the ancient domestic architecture of our own country, where, even in residences of the highest class, the staircases were generally very confined, placed within turrets, and exceedingly steep and narrow: narrow not only as regards the actual width of passage up and down, but as regards the diameter or space occupied by the whole, there being no *well*, or central opening, but the steps winding around a solid newel; so that, in ascending or descending, a person is continually revolving, without any "foot paces" for resting upon, and cannot see whether he will encounter any one else. *Turnpike* was a term formerly applied to staircases of this kind; also *vise*, from their spiral or screw-like shape, whence the more modern appellation of *corkscrew* stairs, corresponding with the Italian *scala alla lumaccia*, or *scala alla chiocciola*, with the French *escalier à limaçon*, and the German *wendeltreppe*.

It was not till about the time of Elizabeth that staircases began to be planned more commodiously in this country, and were made a decorative feature in the interior of a mansion. But though they were greatly improved, the flights being made wider, and the steps parallel to each other, with intermediate landings or resting-places between the several flights, and although considerable decoration was bestowed upon them,—the walls being panelled, and the parapet of the stairs formed either by richly carved balusters or open fretwork, frequently with heraldic figures of animals on the pedestals at the angles of the different flights,—the staircase itself was usually inclosed within a comparatively small area, so as to admit of no general view of the whole of it, there being very little open space, or *well*, as it is termed, sometimes none at all. The staircases at Aldermaston, Berks; Crewe Hall, Cheshire; and Knole, Kent, may be taken as examples of the kind. At a later period, staircases in mansions of a superior class were made disproportionably spacious, being upon a scale as to size with which the apartments themselves were not at all in keeping.

The planning of a staircase is generally considered one of the most difficult matters in internal architecture, and it is certainly one that requires great consideration. Yet there is no particular difficulty, except where, as is generally the case in moderate-sized houses, the architect is cramped for room, more especially if, while restricted in that respect, the ascent from one floor to another is greater than usual. The number of stairs, and the space required for the convenient arrangement of them, are easily estimated when the height of the ascent from one floor to another is given, and the dimensions are determined for the risers and treads. Stairs are technically described as consisting of *risers* and *treads*, the former being the fronts or heights of the steps, and the other their flat surfaces or breadths. Stairs are further distinguished as being *flyers*, those which ascend straightforward; and *winders*, which having their treads triangular, coming quite to a point at their ends near the balusters, afford no footing there, and ought consequently to be avoided whenever it is at all practicable to do so. A *flight* is a consecutive series of stairs in the same direction, or between one *quarter-space* or *half-space* (*palier*) and another, which last are short intermediate landings, serving to lessen the fatigue of a continuous ascent, by subdividing it into shorter flights. For the area containing, or rather constituting, the staircase itself, we have no distinct term in addition to the general one, similar to the French *cage*, the Italian *gabbia*, and the German *treppenhaus*.

We proceed to notice the most convenient proportions of the stairs themselves as to height and breadth for their length. As to the breadth of the flights, that is comparatively arbitrary: it should never be much less than 4 feet, so as to allow two persons to pass, except in back-staircases; but it may be as much more as the space will permit, or the effect aimed at in the design may require. The best general, and what may be considered standard, proportions, are 6 inches for the risers and 12 inches for the treads; though from 6½ to 7 inches may be allowed for the former, and only ten for the latter, in secondary staircases. In those of a very superior kind, on the contrary, the risers do not exceed 5 or even 4 inches (less height than which last would be more fatiguing than convenient), and their treads are then made from 14 to 16 inches. The height, therefore, to the landing of the floor to be reached being given, it is easy to calculate either how many risers of a certain number of inches will be required; or what must be the dimensions of the risers and treads, in order to ascend within the space allowed. Supposing the first-mentioned height to be 14 feet, and the risers 6 inches, two risers will be equivalent to 1 foot of ascent, and consequently twenty-eight risers will be required, or twenty-seven treads, the upper landing being the tread to the last riser. In such case, hardly less than an area of 20 by 8 feet, on the level of the upper floor, would be sufficient for the staircase, unless there were winders instead of quarter-spaces, or of a single half-space between the two flights. The number of risers required is ascertained by reducing the given altitude of ascent to inches, and dividing it by the height of the risers: thus, taking the altitude as before (14 feet), and the risers at 5 inches, there must either be 33 risers a trifle more than 5 inches each, or 34 a trifle less. Rondelet gives the following very simple formula for calculating the dimensions of the treads and risers respectively, namely, calling h the riser, and t the tread, $2h+t=2$ feet; it is based on the principle that the ordinary length of a pace is equal to 2 feet, and that the effort exercised in lifting the leg vertically is double the effort required to move it horizontally.

Palladio, and others following him, have laid it down that the staircase ought to be seen immediately on entering a building; but it is impossible to establish any positive rule for what must depend upon particular circumstances, and this is by no means the best general arrangement. In a public building or place where strangers go in and out without inquiry, it may be desirable that the staircase should present itself at once; but certainly this is not the case in private mansions. On the contrary, it is in every respect better that the staircase should be kept out of view until the first vestibule has been passed through, and that it should be placed in a position as remote from the entrance into the house as the plan will admit, both in order that the approach to it may be lengthened, and that, in case it has any architectural pretensions at all, it may strike the more by not coming into view at once. At all events, only the lower part of the staircase —no more than is sufficient to indicate its situation—should be visible from the entrance, otherwise it will be inconveniently exposed; and if there are doors to several rooms on the upper landing, persons passing from one to the other would be seen from the hall. It is therefore a great error to place the staircase, as is sometimes done, in the first or entrance hall of a mansion, because, in addition to the inconvenience just pointed out, such hall must be made the height of two floors, and consequently, if otherwise suitably proportioned to such height, it will be the most spacious and loftiest room, and so far be attended by a degree of effect which, instead of being afterwards increased or kept up, is greatly diminished. Such arrangement also cuts off the communication above between the rooms on one side of the hall and those on the other, except there is a gallery or continuation of the landing carried over the entrance.

Even when kept apart from the entrance-hall or other vestibule, a staircase will always be sufficiently striking in proportion to the rest of a house, because it will produce greater architectural effect, and be loftier than the rooms themselves. We are now speaking only of what is usually termed a "grand staircase," leading up no higher than the principal floor, so that the whole of the space from the level of the landing is perfectly clear, and there are no flights leading up higher, for if there were, the space over head would appear encumbered and confused. There is in fact no part of an interior which accommodates itself more readily to architectural character and display, or which admits of greater variety of design both as to plan, section, and decoration, than a staircase of the kind just referred to. If the house itself be not upon a very large scale, there is danger of doing here rather too much than too little. In regard to altitude, there will here always be greater magnitude than elsewhere; if therefore corresponding magnitude of area be given to it, the staircase will overpower everything else, cause the rooms to appear small by comparison, and appear in itself too large for the house. It is therefore desirable to make the area, at least the visible area of the staircase, rather less than more than that of any of the principal rooms. It is also rather a solecism to affect magnitude of space in other respects corresponding to that of height. While it serves as a contrast to the apartments, loftiness or excess of height, as compared with length and breadth, is as much an appropriate characteristic of a staircase as it is of a tower. Its altitude therefore from the bottom of the first flight to the ceiling, may very properly be made between two or three times the breadth. Accordingly it will be found expedient to enclose the landing, if continued quite round the staircase, not merely by a screen of columns, but in such manner as to shut it out from view, with only partial openings at intervals, in order to avoid too much spaciousness on that level, and to keep the *cage* of the same size from bottom to top. Of such staircase upon a large scale there is an example at Taymouth Castle, the seat of the Marquess of Breadalbane, which is about 40 feet square by 100 feet in height, with an upper corridor surrounding it, with open arches.

One of the most simple and effective yet least common arrangements of a staircase, is that which may be described by the term *avenue staircase*, the stairs being continued in a straight line, though broken by *spaces* into a succession of flights, within what would else be a level corridor or gallery; and occupying its entire width. There is something particularly noble and majestic in a staircase of this kind, for although it may be narrow, considered as a gallery, it looks unusually spacious as a staircase, the *flight* itself being wider than those of staircases placed within a much larger area; besides which, the whole is more regularly disposed, and forms a more striking piece of perspective. Still, simple as such plan is in itself, it is by no means adapted to general application, because, although it requires only moderate width, it requires considerable length, short flights, and ample spaces between them, and stairs with low risers and broad treads; otherwise, the descent, as viewed from above, being in a straight line, looks precipitous, or at least has no dignity of appearance. Another circumstance which limits a staircase of this kind to particular cases, is, that in order for it to produce proper effect, the height to be ascended should be very moderate, hardly more than seven or eight feet; for else, the space at the foot of the stairs looks confined, and the upper flights scarcely show themselves from that station. Hence, though it may be referred to as an instance of an avenue staircase, the one leading to the keep or round tower at Windsor Castle, is more remarkable than beautiful or grand, leaving decoration out of the question; the altitude ascended being so very great. Sir John Soane has given some ideas of the kind in his designs for a 'Scala Regia'—a favourite subject with him. The staircase of the Chamber of Peers at Paris, designed by Percier and Fontaine, was an example of the kind, but not the best, for the ascent was so great that the columns on its sides, on the same level as the landing, looked quite insignificant. The National Gallery, again, afforded instances of a different modification of the same arrangement, half the ascent being by an external flight in the vestibule, the remainder by another within the corridor leading from it; and though not exactly suited for such a building, the idea is pleasing in itself and would produce a striking effect, in one of less pretension.

In public edifices or large mansions, whatever be the plan of the principal staircase, it is generally *branched*, that is, there is first a wide central flight, and then two other narrower ones branching off from it one on each side, either at right angles to it or as return flights parallel to it; and it is hardly necessary to observe, that in all such staircases the *foot-spaces* are large, and that there are no winders. Extreme care should, however, be taken in planning staircases of this (or indeed of any) description for places of public resort, as theatres, concert-rooms, &c., to so design them as to produce the least possible hindrance to the rapid passage of the audience in case of the occurrence of a panic. The branched staircase at Goldsmiths' Hall, which is parted off from the vestibule by a glazed screen, is an example of more than ordinary splendour, being lighted by a dome. The branching flights at right angles to the first, lead to a landing on each side, which has a double screen of Corinthian columns, so that the view across from side to side, in the upper part, is unusually rich. At Buckingham Palace, there is first a very wide flight, entered from between columns, branching off right and left in curved flights, the cage, which is about 36 by 26 feet, being curved elliptically on those sides or ends. In this example, the stairs rest upon a graduated podium or wall enclosing the space immediately beneath, which serves as a private passage behind; a mode frequently adopted in similar cases, being one which contributes to solidity and nobleness of appearance, and prevents that mass of shadow beneath the stairs which gives a gloom to the lower part of the staircase.

Instead of there being a central flight below, the ascent frequently begins on each side, and is carried up in one or more flights to the common landing, where both branches terminate; from which point the stairs are sometimes continued, returning in an upper central flight, which is carried across an arch thrown from that landing or half space, to a higher landing. Staircases of this kind, which may be termed *bridge* staircases, occur in the Custom House and the Auction Mart. Their effect, however, is not good, because the upper suspended flight or *bridge* darkens the lower part of the staircase, and has a strangely awkward cumbersome appearance when viewed from that station. At the best, therefore, they are suitable only for places of evening resort, where they can be lit up below as well as above.

The staircase of the Fitzwilliam Museum, Cambridge, claims notice, not only on account of the richness of the general design, but of some peculiarities in its arrangement. Strictly speaking however, this example can hardly be given as that of a staircase, according to the usual meaning of the term, the stairs being mere flights of steps in the entrance hall. That in the centre is a broad descending one, leading down to the libraries, which are on a lower level than the hall; and on each side of it is a rather narrower ascending flight to the spacious landing carried around three sides of the hall, and serving as a statue gallery. Though the lower area is only 32 by 26 feet, consequently that of the floor very much less, owing to the space occupied by the flights of steps, that of the upper part on the level of the landing is 68 by 44 feet, the landing itself being about 17 feet wide. In some degree similar in plan, although very different in design, is the hall at Holkham, the seat of the Earl of Leicester, which has a noble flight of steps within a recess or tribune enclosed by columns which are continued along the sides of the hall.

The grand staircase of the Reform Club-house, London, is an example, somewhat unusual in this country, though common enough in Italy, of what may be called an *enclosed* staircase; the flights are shut up between walls, and consequently there is no open *well*, nor can the whole be seen at one view. A plan of this kind therefore differs from the avenue staircase, merely in not being carried straight-forward, but either returning in a parallel flight from the half-space or first landing, or having the second flight at right angles with the first. The last is the case at the Reform Club-house, where the staircase consists of three enclosed flights, the last being a return one to the first, and landing upon the gallery around the upper part of the inner hall or saloon. That at Burleigh too is similarly planned. The same mode may be adopted for circular or semi-circular as well as rectangular plans; and one advantage attending it is, that while the ascent itself is as spacious and commodious as if the whole were entirely open, there may be a secondary staircase for servants, shut up within the larger one.

The architectural effect of a staircase will greatly depend upon the mode of lighting it. Where it is carried up only one floor, the best mode is to light it entirely from above, either through a dome or lantern in the ceiling, or by making the upper part of the walls just beneath the ceiling a continued lantern. If there are windows on the landings of the several flights, the effect will be improved by their being filled with stained glass, especially if towards a back court; or, if a conservatory can be carried out on the level of the first landing, so as to show itself through glazed folding-doors, a very pleasing and cheerful effect is obtained, even though the conservatory itself should be hardly more than a glazed veranda. As to material, stone is greatly preferable to wood for stairs, if only on account of greater security in case of fire; in lieu of stone, cast-iron may be employed. Marble is very rarely used for stairs in this country, and whenever it is, it should be left unpolished on the treads, or it would be dangerous to descend them. The same remark applies to stairs of wainscot, unless they are carpeted nearly their entire width.

STALL-FEEDING. The feeding of cattle in stalls for the purpose of fatting them more readily than by simple grazing, and at a time when they cannot get fat on pastures, as a regular part of the process of husbandry, is comparatively modern. In former times cattle were slaughtered in October and November, which latter, in most languages derived from the Teutonic, is called *Slaughter-month*, there being no possibility of buying fresh meat of any degree of fatness during winter, and salt meat was the food of all classes in that season. But now the process of fatting cattle goes on without interruption during the whole year, and fat beasts come as regularly to market in winter as in summer. Stall-feeding is now the principal means by which oxen and cows are rendered fit for the market.

It has been observed, in the article SOILING, that one object of that system was to save the waste of food which is occasioned by the treading of cattle in pastures, and by their choosing the sweetest grasses to the neglect of the coarser. The principal object however is to save the manure, which in the pastures goes to waste, but in the yards or stall is all preserved. In stall-feeding another object is looked to, that of increasing the substance of the animal, especially the fat; and to do this judiciously and with profit requires much experience and attention. It has been proved that animals require a certain portion of meat and drink to keep them alive, and that this quantity, in the same species, is in general in proportion to the weight of the animal. If an animal has his exact ration of food, he will continue in health, but he will not increase in weight: in this case therefore it only produces a certain portion of manure, which is not equivalent to the food consumed. If a larger quantity be given, the animal, if in health, will increase in weight, and the more food he has, within a certain limit, the faster will be this increase: but there is a point where increase stops; and if by any means the animal is induced to take more, his stomach will be deranged, and he will become diseased, and occasion loss by over-feeding. It is consequently of great importance to the stall-feeder to ascertain what is the exact quantity of food which it will be most profitable to give to a stall-fed animal. Experience alone can teach this: but some rules may be given which will enable any one who wishes to stall-feed cattle not greatly to err in his mode of feeding, and soon to find out what is the most profitable course to pursue. For this purpose it is essential that after having ascertained by experiment the quantity of food which will give the greatest increase of flesh per week on a certain weight of beasts when put up to fatten, all the food given to the cattle be carefully weighed, and no more be given in any day than is needful. The quality of the food should also be attended to; for a truss of fine well-made clover, lucern, or sainfoin hay, may contain double the nourishment of another truss of coarse marsh hay. The best kind of food should always be reserved for fatting cattle. Roots alone are too watery, and must be corrected by dry food, such as straw cut into chaff, or good hay, and especially farinaceous food, whether it be corn ground or bruised, or oil-cake. By a judicious mixture of food a much greater increase of flesh may be produced than by an irregular mode of feeding, however good the quality or abundant the quantity given may be. To overfeed is as unprofitable as to starve a beast, and produces similar effects. It is of great importance that the cattle should be fed with great punctuality, at certain hours during the day, and that the troughs should be cleared of all the remains of food which they do not eat at each time of feeding. Rest and sleep are great aids to digestion, and a little gentle exercise after sleep prepares the stomach for a fresh supply of food. Air also is highly conducive to health; and hence those beasts which are allowed to move about in a loose stall, or a small yard protected from the rain and wind, thrive better in general than those which are tied up. It is the practice of many good feeders to put oxen in pairs in small stalls, partly open, so that they may be in the air, or under shelter, as they prefer; and the finest oxen, if not the fattest, are prepared for the market in this way. Experience shows that all domestic animals like company, and that they are more contented and quiet when they have a companion than when they are alone. This is the reason why they are put up in pairs. Whatever promotes the health and comfort of the animal will be most profitable to the feeder. When a beast has acquired a certain degree of fatness, it is a nice point to decide whether it would be best to send him to market or continue to feed him. This is often decided by mere caprice or fancy; but if the food has been weighed, and the weekly increase of the beast is noted, which is best done by weighing, but may nearly be guessed by measuring, it becomes a mere question in arithmetic to determine whether his increase pays for his food and attendance; if it does not, there is a loss in keeping him; and if a lean animal put in his stead would increase faster on the same food, every day he is kept there is a loss of the difference between the increase of the two. The pride of producing a wonderful animal at a fair or show may be dearly paid for, and must be put down to the account of luxuries, like the keeping of hunters or racehorses.

The most profitable food for fattening cattle is, in general, the produce of the farm: the expense of all purchased food is increased by the profit of the dealer and the carriage of it. And the only compensation for this additional cost may be in increasing the manure, where the straw and roots of the farm are deficient: in that case oil-cake, or even corn, may be purchased with advantage, since by means of the manure crops may be raised which without it must fail. The stalling of cattle, as well as the fatting of pigs, is in many situations the best means of carrying the produce of the farm to market. An ox can be driven many miles, whilst the food he has consumed would not repay the carriage, and all the manure would be lost, and must be purchased at a great expense, if it can be had at all. If a farmer can feed cattle, so as to pay him a fair market-price for the food consumed, and something for the risk of accidental loss, he may be well contented to have the manure for his trouble: few stall-feeders get more than this in the long run.

It may be proper to add to the above, that the box-feeding where the animal is loose in a space about 10 feet square, is more conducive to health than stall-feeding where the animal is tied by the neck. The box is littered every morning, and the animal is thus kept dry and clean without the removal of the soiled litter, which thus kept from exposure to air and rain, ultimately yields a much more fertilising manure than that of the ordinary dung-heap.

STAMMER. The terms stammer and stutter are synonymously adopted to denote the involuntary interruption of utterance arising from difficulty and often total inability to pronounce certain syllables, the speech apparatus being frequently affected with spasm in the effort to speak.

In some stammerers the spasm consists of involuntary movements similar to *chorea* (St. Vitus's dance), which occasionally affects other than the speech muscles. Stammer with this spasm distorts the utterance by an involuntary repetition of some part of the syllable, as ge-ge-ge-good de-de-de-day. The repetitions may or may not be vocal. In other stammerers the spasm consists of involuntary immobility, similar to *tetanus* (lock-jaw), commonly of the form termed *trismus*, in which the mouth is closed, and the jaw cannot move to open it; and sometimes of the form termed *antitrismus*, in which the mouth is open, and the jaw is equally incapable of moving to shut it. Stammer with this spasm distorts the utterance by an involuntary extension of some part of the syllable, as l——augh, where the *l* is much prolonged.

In the looseness of language resulting from inexact knowledge, all kinds of difficult and defective utterance are misnamed stammer; as the difficult utterance of the intoxicated, the faltering utterance of the paralytic, the imperfect utterance of deep emotion, as of fear, the defective utterance of malformed organs of speech, and the hesitation in discourse when the suitable word fails to present itself to a speaker's mind. Such affections of the utterance, however, are distinct from stammer, for

1. The stammerer's inability to pronounce words remains during health, soberness, calmness of mind, and also when the appropriate words occur to him.

2. The stammerer feels his difficulty of utterance essentially to consist in a refusal of some part of the speech apparatus to obey his will.

3. The stammerer's utmost efforts to force out any difficult word commonly excite spasm, and increase it if it previously existed.

4. The stammerer's inability to speak is intermittent: the same syllable is not always equally difficult to utter, and is sometimes uttered with ease.

Those circumstances will distinguish stammer from the misnamed stammer of paralysis, intoxication, &c.

Now, to understand the nature of stammering, it is necessary to know the audibility and mechanism of utterance, which may be thus briefly described:—

The voice is produced in the larynx, whence it issues into the pharynx. The pharynx opens into the nose and into the mouth; and by means of a curtain valve, named the *velum pendulum palati*, we can direct the issue of breath through the mouth or the nose, or through both mouth and nose at once. The voice is produced in the larynx, an audible sound, which may possess the distinctions of song-notes (musical sounds), as those of pitch, loudness, and quality; or it may possess the peculiar conditions of those distinctions which constitute speech notes. In the pharynx and mouth the volume of voice is magnified, and its quality is modified.

Observation and experiment concur to prove that the production of voice is an acoustic phenomenon depending on mechanical principles similar to those which regulate the production of sound from an inanimate instrument; for it is now agreed that the upward current of air passing through the larynx produces an effect on the vocal ligaments precisely similar to what it would if the larynx were an inanimate mechanism. The voluntary power over the larynx adjusts it to be acted on by the current of air, and thus the voice is to be regarded partly as a mechanical and partly as a physiological result.

Observation and experiment concur to prove that the modification of voice into speech is also an acoustic phenomenon depending on principles similar to those which regulate the modification of sound by an inanimate instrument; for it is now agreed that the modification of voice into speech in passing through the variable cavity of the pharynx, mouth, and nose, produces an effect precisely similar to what would be produced if the variable cavity were an inanimate mechanism.

Thus both in voice and speech the production and modification of vocal sound depend on the laws of acoustics, while the adjustments of the various parts of the apparatus which produce and modify the voice depend on voluntary muscular movement. The one is mechanical, the other physiological.

It is familiarly known that the movement of every organ is effected by muscular contraction; that both voluntary and involuntary contraction of the muscles depend on the nerves; that all voluntary contraction is regulated by the brain; and also that the voluntary contraction of one muscle is accompanied by an adjusted voluntary relaxation of its antagonist muscle.

The speech apparatus may be considered as consisting of the lungs or bellows, which can send a current of air through the trachea or windpipe to the larynx, which is situated on its summit. In the larynx this current of air can be vocalised at will into song, or into speech-sounds, which, on passing through the variable cavity, consisting of the mouth, pharynx, and nose, can be further modified into speech. Thus the speech-apparatus, as a whole machine, consists of the respiratory, the vocal, and the enunciative organs.

The respiratory apparatus consists of the chest, the lungs, and the air-passages. The respiratory movements are involuntary and periodic; the inspiration of breath alternates with its expiration; and in both acts the breath flows in a continuous stream. There is a periodic action of the inspiratory muscles, but whether their action alternates with an action of the expiratory muscles, or simply with the spontaneous return of the parts by their elasticity and gravity, is yet undetermined. The muscular actions during the tranquil respiration of repose appear to be limited to periodic inspiratory movements.

The movements of respiration include the motions of the diaphragm, the abdominal and thoracic muscles, and those of the larynx, which dilate and contract the aperture of the glottis. The nerves engaged in these movements are the phrenic, the spinal accessory, the vagus, many of the spinal nerves, and the portio dura of the seventh. The will can influence and somewhat modify the movements of respiration; thus we can prolong or shorten the duration of an inspiration, and we can delay or hasten to begin one. We have similar control over the expiration of the breath; and we have power also to limit, or nearly so, the movements of respiration to sub-groups of muscles: thus we can breathe by the diaphragm alone, or by the ribs alone.

Indeed in the act of vocalising, whether for speech or song, the involuntary is almost superseded by the voluntary act of respiration. The will gives a different play to the chest. We breathe less by the diaphragm and more by the ribs; we shorten the duration of the inspiration and completely change the character of the expiration.

There are two modes of involuntary respiration: in the one, the breath issues in one continuous unbroken stream, as in the ordinary breathing of unruffled tranquillity, which by some emotions is hurried and involuntarily vocalised, producing sighs, groans, &c.; in the other mode the stream of breath is interrupted so that it issues in detached portions, which during some emotions is also involuntarily vocalised, producing laughter, crying, &c.

The will has power to produce voluntary expirations in both modes. The unbroken stream is termed the exhausting breath, which is often required for a long-drawn note in song. The broken stream is termed the holding breadth, which is constantly required in lengths suitably adjusted to the demands of the syllables as they occur in speech. The general conditions of respiration, vocalisation, enunciation, and articulation, under which stammer occurs, are subjoined.

I. *Respiration.*—1. Most stammerers manage their respiration badly, although nearly all can speak freely in a whisper. 2. They feel that they have insufficient breath to speak. This sensation, however, arises less from an insufficiency than from attempting to speak on an involuntary inspiration. The breath is expired to be vocalised by the voluntary action of the ribs, which mechanically contract the chest's cavity. The ribs, however, cannot accomplish this when they are in the position in which an involuntary inspiration leaves them; they must be raised to that position to which a voluntary inspiration carries them, before they can act with mechanical effect on the chest to expire a holding breath for the purpose of conversation. 3. With the sensation of insufficiency of breath, some feel also a pain at the pit of the stomach. This pain is connected with attempting to speak on an involuntary inspiration, and its severity is commonly increased by struggling to speak.

II. *Vocalisation.*—1. *Song-voice.* The song condition of voice seldom presents any difficulty to stammerers. Cases of stammer in the song-voice occur but rarely.

2. *Speech voice.*—Stammer occurs in all parts of the speech-note, more frequently, however, in the middle than towards the end, but most commonly at the initial.

3. *Pitch of Voice.*—Changes of pitch, whether concrete or discrete (slide or skip), through narrow intervals of the scale, present difficulties which wider changes of pitch do not. Stammerers can mostly declaim, if they cannot converse or quietly read; and it is well known that wider intervals of pitch occur in declamation than in ordinary conversation.

4. *Loudness of Voice.*—When the loudness of the speech-note is of the form of the musical *diminuendo*, which begins abruptly and gradually diminishes in loudness, as thus figured $>$, a difficulty is presented to the stammerer which does not occur if the form be the musical *crescendo*, where the note begins feebly, and gradually increases in loudness, as thus figured $<$.

5. *Quality of Voice.*—The conversation tone presents a greater difficulty than the falsetto, or than the full enriched voice of epic declamation.

6. *Quantity or Duration of Syllables.*—Short and inextensible syllables present a greater difficulty than the long and extensible.

7. *Accent.*—The unaccented syllables of discourse seldom offer any difficulty to stammerers. The element, or combination of elements, which is difficult to utter with accent, is easy to utter without accent. The accent given by stress is infinitely more difficult than that given by extended duration.

8. *Rhythmus.*—The measured movement of verse is easier for the stammerer than the unmeasured movement of prose and conversation.

III. *Enunciation.*—Syllables are of two kinds, namely :—

1. Those composed of one elementary sound.
2. Those composed of more than one elementary sound.

1. *Vowels.*—A vowel alone may constitute an accented syllable, and even a whole word, of which the pronoun *I* and the article *a* are familiar examples. Stammer often occurs on such syllables.

2. *Consonants.*—When two or more are combined together without a vowel to form a syllable, they occur only as unaccented final syllables of words. The stammerer's difficulty is less to utter the elementary sounds singly than to articulate them so as to form syllables.

IV. *Articulation.*—The elementary sounds are articulated in three orders of succession :—

1. The vowel followed by a consonant.
2. The consonant followed by a vowel.
3. The consonant followed by a consonant.

Stammer occurs in each of these modes of articulation. There is seldom any difficulty in articulating two consonants together; some, however, is felt in postfixing a consonant to a vowel, and the greatest is felt in adding a vowel to a consonant.

To these general conditions of voice and speech under which stammer occurs, may be added other conditions, such as sex and age. A majority of stammerers are males; and few of either sex stammer from their infancy; children commonly speak freely until about five years of age. An occasional difficulty is first observed, which becomes more frequent up to the tenth year, when it is commonly at its maximum; although the spasm frequently increases in severity up to manhood. In the decline of life sometimes the stammer spontaneously diminishes, and it has been known to entirely disappear. The voices of childhood and old age differ in several respects from that of the intermediate period of life. The speech melody of infancy is set in a high pitch, which often runs into the falsetto, and is much intersected with wide intervals both concrete and discrete. The loudness is chiefly of the *crescendo* form on long whining quantities. The voice of old age often falls into the tremulous scale, the rate of utterance is slow, steady, and uniform. The loudness is not often of the *diminuendo* form, and is on extended quantities. The accent is given to syllables by quantity rather than by stress, deliberate pauses are made, and the whole style is marked by the self-possession of experienced age conversing with a consciousness of superiority, if in nought else, in a longer reach of memory. Sudden changes of temperature, especially from a high to a low temperature, likewise tend to increase a stammer.

The *Varieties of Stammer* are many. They all arise from—1. Difficulty to produce voice; 2. Difficulty to produce voice in quantities adjusted to the syllable's demands; 3. Difficulty to produce the elementary sounds; 4. Difficulty in joining such sounds together; and in each of these classes there are varieties.

Variety 1 arises from ill-regulated respiration, in which the effort to vocalise is accompanied with a feeling of insufficiency of breath. The stammer proceeds from an attempt to speak on an involuntary inspiration. A holding breath cannot be maintained on an involuntary inspiration, and therefore voluntary respiration for speech must always begin with an inspiration of breath. The physiology of this stammer indicates a discipline for its removal. The organs of respiration must be drilled to rightly change the involuntary act of respiration to the voluntary, which, with a course of rhythmus, will effect a permanent cure.

2. The difficulty in producing voice which is occasioned by an involuntary closure of the glottis. In this variety of stammer, instead of the larynx receiving the adjustment for vocalisation in ready obedience to the will, the glottis suddenly closes, either by an involuntary associate movement, or by a tetanic spasm, probably in most cases by the latter. Dr. Arnott pointed out the nature and means to cure it. His remedy consists in keeping open the glottis, by issuing a drone sound, such as the *e* of the word berry, before beginning to speak, and in joining this prefixed drone to the words. See his 'Elements of Physics,' vol. i.

3. The difficulty in producing voice which is occasioned by an involuntary twitching of the glottis similar to chorea. This spasm is sometimes so excited as to preclude vocalisation, when only short iterations of breath are audible. The glottis must be disciplined on sounds of the *crescendo* form of loudness in a low pitch, and proceed gradually from the song-voice to that of speech. Respiration and speech-voice training will follow, accompanied with general rhythmic discipline to the whole speech-apparatus for reading and speaking both verse and prose.

4. In this variety the difficulty is not to produce voice, but to control its quantities. Vocalisation freely takes place, but the event of two or three short or accented syllables following near together throws the glottal muscles into choreal spasm. The principles of discipline for the spasm will be similar to the preceding variety of stammer; while a distinct discipline must be projected to acquire a higher degree of associating power.

5. The difficulty of uttering a vowel of uniform sound is a voice stammer, it being an absence of voluntary control over the vocalisation of the breath. The difficulty of uttering a diphthongal vowel may be either a voice or a speech stammer, and is often a combination of both. When the difficulty is to produce voice to begin the vowel, the stammer is vocal; and when the difficulty is to change the adjustment from that for the initial, to that for the final sound of the diphthong, it is a speech stammer. When the difficulty is to produce voice to begin the consonant, the stammer is vocal; and when the difficulty is to change the adjustment from that for the initial to that for the final sound of the consonant, it is a speech stammer. Stammer on the single elementary sounds of speech can be permanently remedied only by a systematic training of the disobedient organ which occasions it. The organ must be disciplined to perform the necessary movements under all conditions of voice, which, accompanied with a general training of the whole apparatus of speech, conducted on rhythmical principles, will effectually remove the stammer.

6. Stammer occurs in all three modes of articulation, namely :—

A consonant followed by a vowel, as *bee;* a vowel followed by a consonant, as *ebb;* a consonant followed by another consonant, as *bl* of the word *bled.*

The difficulty in articulating the elementary sounds of speech to form syllables, can be permanently remedied only by a systematic training of the disobedient organs to perform their required movements for the several adjustments of the mouth which are necessary to articulation. The training must be general and special. The general is a rhythmic training of the whole speech-apparatus; and the special is a training of the disobedient organ to perform its various movements in articulation.

Our analytic description of stammering reveals three functional causes of inability to control the muscular movements which are required for utterance, namely :—

I. Spasm, both of the tetanus and chorea forms. All muscles are liable to spasm. Spasm of the larynx, the tongue, the lips, and the masseter muscle, are each sources of stammering.

II. Defect in the associating power, which combines the voluntary movements of different organs in one simultaneous act, or in an allied succession of acts. Defective association of vocalisation with respiration will occasion stammer; for perfect association of the voluntary movements of the larynx with those of the chest are required in utterance. The movements of the larynx and chest are effected by means of the laryngeal, the recurrent, and the expiratory nerves.

III. Involuntary associate movements; as after mimicking a stammerer it has been found that those muscular movements, which in the mimicry were *voluntarily* associated with the proper movements of utterance, have suddenly become linked to them so firmly in allied motion, that the mimicker is unable to dissociate them, and an actual stammer results.

The adoption of appropriate remedies for stammering then will depend on the following conditions, namely :—1. On the part of the speech-apparatus which is affected; 2. On the cause producing the stammer; and 3. On the vocal and other conditions under which the utterance is least affected. The appropriate remedies for each are treated of in several works on the subject, among which we may mention Thelwall's 'Letter to Clive on Stammering;' Cull's 'Observations on Impediments of Speech;' Cull's 'Stammering Considered;' and J. Hunt's 'Treatise on the Cure of Stammering.'

STAMPING, STAMPING PRESS. The important manufacturing process of stamping will be found sufficiently described in several foregoing articles in this work; such as BRASS; BUTTON; CHASING; COPPER; MINT; NEEDLE, &c. In most varieties of the operation, the substance to be treated is in the form of a thin sheet. The pattern is engraved on two dies, one placed below and one above the plate; and the impression is given by the upper die being made to fall forcibly upon, or being forcibly driven into, the plate. The lower die is generally a reverse of the upper, the one being in cameo and the other in intaglio; that is, any part of the device which is convex or raised in the one, is concave or sunk in the other.

STAMPS, STAMP ACTS. Stamps are impressions made upon paper or parchment by the government or its officers for the purposes of revenue. They always denote the price of the particular stamp, or in other words, the tax levied upon a particular instrument stamped, and sometimes they denote the nature of the instrument itself. If the instrument is written upon paper, the stamp is impressed in relief upon the paper itself; but to a parchment instrument the stamp is attached by paste and a small piece of lead which itself forms part of the impression. These stamps are easily forged, and at various times forgeries of them upon a large scale have been discovered. The punishment for the forgery of stamps was long a capital offence; it is now punishable by imprisonment or penal servitude.

In France stamps are used both for the authentication of instruments and as a source of revenue: thus they constitute a large part of the income of the municipality of Paris.

The stamp tax was first introduced into this country in the reign of William and Mary, such an impost having previously existed in Holland. The act 5 W. & M., c. 21, imposes stamps upon grants from the crown, diplomas, contracts, probates of wills and letters of administration, and upon all writs, proceedings, and records in courts of law and equity; it does not however seem to impose stamps upon deeds, unless these are enrolled in the courts at Westminster or other courts of record. Two years afterwards, however, conveyances, deeds, and leases were subjected to the stamp duty, and by a series of acts in the succeeding reigns every instrument recording a transaction between two individuals was subjected to a stamp duty before it could be used in a court of justice. By the 38 Geo. III. chap. 78, a stamp duty was imposed on newspapers (which was only taken off a few years ago), [Newspapers], and by an act of Geo. IV., inventories and appraisements are required to be stamped. Stamps are also used as a convenient method of imposing a tax upon a particular class of persons: thus, articles of apprenticeship are subject to duty, and so are articles of clerkship to a solicitor. Solicitors and conveyancers are required to take out annually a stamped certificate, and before a person commences practice as a physician, an advocate, a barrister-at-law, or an attorney, he must pay a tax, under the form of a stamp upon an admission. Notaries public, bankers, pawnbrokers, and others must obtain a yearly licence in order to exercise their callings.

It is only possible thus generally to point out the nature of the things subject to stamps, as these have varied frequently, and are subject indeed to constant change. It is enough to refer to the stamps on newspapers and letters as an example. And it may be added here that it is only recently that the system of levying a tax by means of stamps on legal proceedings has been revived, after having been abandoned for a great many years.

The general principle which regulates the courts in the interpretation of the stamp acts is, that on the one hand fraudulent evasion of the stamp duties shall be punished by forfeiture of all benefit from the document which ought to have been stamped; and, on the other hand, that a just claim shall not be evaded or a fraud be effected because the just claimant has unintentionally violated the stamp laws. Accordingly almost all instruments requiring stamps (except bills and notes) may be stamped on payment of a penalty; and all courts of civil justice are authorised to receive the unstamped instrument when tendered in evidence, on deposit of the amount of the stamp and penalty. Bills and notes cannot be stamped after they are made; a provision intended to prevent fraud in the use of these important instruments of commerce.

An unstamped instrument, though in general inadmissible, may be used as evidence to defeat fraud, and, with certain limitations, to establish a criminal charge. Thus, where an unstamped agreement contained matter not requiring a stamp, it was used as evidence of that matter, although invalid as evidence of the terms of the agreement. An indictment for forgery likewise may be maintained, although the instrument forged may be invalid for want of a proper stamp; but such an invalid instrument is not sufficient to support an indictment for larceny.

The stamp duties and the custody of the dies are placed under the superintendence of commissioners, who transact their business in Somerset House, London. It may not be out of place to remark that the endeavour to impose stamp duties upon our American colonies in 1765, was one of the proximate causes of the American revolution.

STANAMYL. [Organometallic Bodies.]

STANDARD OF MEASURE, &c. [Weight, Measure, &c., Standard of.]

STANDARD TEMPERATURE AND PRESSURE. In determining the specific gravity of solids and liquids, the standard of comparison is the weight of an equal bulk of distilled water at 60° Fahr.; and for gases and vapours atmospheric air is the standard at 60° Fahr., and under a pressure of 30 inches. In France the standard temperature is 0°C. (32° Fahr.), and the pressure is 760 millimètres, or 29·922 inches. The unit of density is the volume of an equal bulk of water, at its point of maximum density, namely, 39°·2 Fahr. [Specific Gravity; Heat.]

STANDARDS are those trees or shrubs which stand singly, without being attached to any wall or support. In gardening and planting they are distinguished into three kinds, the full standard, the half standard, and the dwarf standard. The full standards are trees whose stems are suffered to grow seven or eight feet or more without allowing side branches to be developed, but at this point are allowed to spread in all directions. In this way most fruit-trees, with the exception of the vine, may be grown, though many of those of the almond tribe, as the peach, apricot, &c., are best grown against a wall. The various kinds of apple, pear, and plum trees are grown as full standards. In fruit-trees the primary branch or stem is often cut off at a certain height for the purpose of favouring the lateral growth; but in forest-trees grown for the sake of timber or for ornament, this treatment is never resorted to.

Half standards are those plants which are allowed to run up three or four feet and then permitted to branch out. The height at which it is desired a tree should branch out may be frequently secured by cutting off the lower branches up to that point, or by cutting down the primary branch and allowing the highest lateral branches to developе themselves. Many shrubs grow naturally in this manner, and when fruit-trees are grown in this way, it is done as a matter of convenience for gathering the fruit, or ensuring their growth under particular circumstances.

Dwarf standards are those plants whose stems are only allowed to reach a height of one or two feet before they are permitted to branch, and this object is effected in the same manner as in the last. All kinds of fruit-trees, as apple, pear, plum, and cherry trees, may be grown as dwarf standards, but these trees do not bear so good fruit under such treatment as when allowed to grow as half or full standards. Gooseberry and currant trees are best treated in this way, and when care is taken to thin them well, they produce by far the finest fruit when grown as dwarf standards of about a foot high. It is in this way that the fruit of the gooseberry has been brought to so great perfection in Lancashire and elsewhere. Many shrubs may be trained as dwarf standards, although in most instances they are more ornamental when allowed to grow as bushes with several stems direct from the ground.

STANETHYL. [Organometallic Bodies.]

STANMETHYL. [Organometallic Bodies.]

STANNARY, from the Latin *Stannum*, "tin." This term sometimes denotes a tin-mine, sometimes the collective tin-mines of a district, sometimes the royal rights in respect of tin-mines within such district. But it is more commonly used as including, by one general designation, the tin-mines within a particular district, the tinners employed in working them, and the customs and privileges attached to the mines, and to those employed in digging and purifying the ore.

The great stannaries of England are those of Devon and Cornwall, of which the stannary of Cornwall is the more important. The stannary of Cornwall, and also that of Devon, were granted by Edward III. to the Black Prince, upon the creation of the duchy of Cornwall, and are perpetually incorporated with that duchy. Both stannaries are under one duchy-officer, called the lord warden of the stannaries, with a separate vice-warden for each county.

All tin in Cornwall and Devon, whoever might be the owner of the land, appears to have formerly belonged to the king, by a usage peculiar to these counties. King John, in 1201, granted a charter to his tinners in Cornwall and Devonshire, authorising them to dig tin and turves to melt the tin anywhere in the moors and in the fees of bishops, abbots, and earls, as they had been used and accustomed. (Madox, 'Exch.,' 279 t, 283 l.) This charter was confirmed by Edward I., Richard II., and Henry IV.

In Cornwall the right of digging in other men's land is now regulated by a peculiar usage, called the custom of *bounding*. This custom attaches only to such land as now is or anciently was *wastrel*, that is, land open or uninclosed. By this mode the bound-owner acquires a right to search for and take all the tin he can find, paying the lord of the soil one-fifteenth, or to permit others to do so; and to resist all who attempt to interrupt him. The bounds must be renewed annually, by a bounder employed on behalf of the bound-owner, or the lord may re-enter.

As part of the stannary rights, the duke of Cornwall, as grantee of the crown, has or had the pre-emption of tin throughout the county, a privilege supposed to have been reserved to the crown out of an original right of property in tin-mines, but which in modern times is never exercised.

The stannary courts were remodelled by the 6 & 7 Wm. IV. c. 106. The duties payable to the duke of Cornwall on the stamping or coinage of tin were abolished by 1 & 2 Vict. c. 120; and further regulations for these courts were introduced by 2 & 3 Vict. c. 58; and the jurisdiction was extended, and the procedure amended and improved by the 18 & 19 Vict. c. 32.

STANNIC ACID. [Tin.]

STANNIC ETHYLOMETHIDE. [Organometallic Bodies.]

STANZA (*Stance*, in French), an Italian word which means room or dwelling-place, is used in poetry to designate certain parts or divisions of a poem, each forming a complete period within itself, and consisting of a number of lines regularly adjusted to each other, and containing every variation of measure or rhyme which is to be found in the whole poem. There is a great variety of stanzas in the poetry of modern languages, according to the rhythm and structure of the poem. There is the terzina of three lines, used chiefly by the Italians and Spaniards; the quartetto (quatrain, in French) of four lines; the sestina, "sixain," of six lines; the ottava, consisting of eight lines, used in epics, &c. Each of these is susceptible of various combinations of measure and rhyme.

STAPHISAGRIA, or **STAVESACRE**, the seeds of the *Delphinium staphisagria*. [Delphinium, in Nat. Hist. Div.] Stavesacre seeds are not now used internally: when introduced into the stomach they cause vomiting, purging, and local ulceration of the intestines, and they may even produce serious general effects. When powdered, they are employed externally for the destruction of lice, or they are dissolved in vinegar and made into an ointment, which is employed for the cure of scabies, which it is said to effect in seven or eight days, and which has found favour in the eyes of some persons, as it does not stain the linen, nor have the unpleasant smell of sulphur. Its external application to abraded surfaces is not free from danger. The only case in which its employment is justifiable is, not to remove, but cause revulsion of, the cutaneous eruption, when, by its sudden drying up, the internal organs are oppressed, as, like most ranunculaceous plants, it causes acute inflammation and pustulation of the skin. It contains an alkaloid, delphine [Delphine], which is a powerful sedative against rheumatic and neuralgic pains. Its internal use requires great caution, and still more its external use as a lotion or ointment, as its absorption through chaps, cracks, or ulcerated places, makes an impression on the nervous system more dangerous than when taken into the stomach. A volatile acid also exists in it, which is powerfully emetic. As this is dissipated at a low temperature, decoction is an objectionable form of administration.

STAPLE, "anciently written *estaple*, cometh," says Lord Coke, "of the French word *estape*, which signifies a mart or market." It appears to have been used to indicate those marts both in this country and at Bruges, Antwerp, Calais, &c., on the Continent, where the principal products of a country were sold. Probably in the first instance these were held at such places as possessed some conveniences of situation for the purpose. Afterwards they appear to have been confirmed, or others appointed for the purpose by the authorities of the country. On the Continent in the staple-towns the goods had to be offered there for sale, and if not bought within a prescribed time might be again exported on payment of a certain toll, and the towns had to provide warehouses where the goods were to be deposited. This rule, however, has been materially modified, and in many cases abolished. In England the arrangement of the staple was made by the king (2 Edw. III. c. 9). All merchandise sold for the purpose of exportation was compelled either to be sold at the staple, or afterwards brought there before exportation. This was done with the double view of accommodating the foreign merchants, and also enabling the duties on exportation to be more conveniently and certainly collected. Afterwards the word staple was applied to the merchandise itself which was sold at the staple. The staple merchandise of England at these early times, when little manufacture was carried on here, is said by Lord Coke to have been wool, woolfells or sheepskins, leather, lead, and tin. Incident to the staple was a court called "the court of the mayor of the staple." This court was held for the convenience of the merchants, both native and foreign, attending the staple. It was of great antiquity; the date of its commencement does not appear to have been certainly known. Many early enactments exist regulating the proceedings at the staple and the court held there. Most of these were passed during the reigns of the two Edwards, the first and the third of that name. These kings appear to have been extremely anxious to facilitate and encourage foreign commerce in this kingdom; and by these statues great immunities and privileges are given, especially to foreign, but also to native merchants attending the staple. The first enactment of importance is called the statute of merchants, or the statute of Acton-Burnel, and was passed in the 11th year of Edw. I. A.D. 1283. [Acton-Burnel, Statute of.] But the statute more expressly directed to this subject was passed in the 27th year of Edw. III. cap. 8, and is entitled the Statute of Staple. One object of it was to remove the staple, previously held at Calais, to various towns in England, Wales, and Ireland, which are appointed by the statute itself.

Matters connected with the staple were not subject to the cognisance of the king's courts, and the king's officers were prohibited from interfering in places where the staple was held. The court consisted of a mayor, who was to be acquainted with the law merchant, and was elected every year by the merchants attending the staple, both native and foreign; he was attended by two constables, also elected by the merchants, and who held their office for life. Two alien merchants, one, as the statute says, "towards the north," probably a German, "the other towards the south," Italian, were to be chosen to be associate in judgment with the mayor and constables, and also six mediators of questions between buyers and sellers. Of these six persons, two were to be Germans, two Lombards, and two English.

In matters of doubt reference was to be had to the privy council. The mayors, sheriffs, and bailiffs of the towns where the staple was held, or there adjoining, were also to attend the mayor and ministers of the staple to execute their commands. Complaints against the mayors were to be redressed by the chancellor and others of the privy council. A prison also was to be provided for the use of the staple, and the mayor and constables had power given them to keep the peace, and to arrest and imprison, their authority extending throughout the town in which the staple was held and the suburbs of it.

The law administered in the court of the staple, so far as regarded all matters connected with the staple, was the law merchant [Lex Mercatoria], and not the common law of the land, nor the custom of the place. If both parties in a suit were foreigners, all the jury were to be foreigners. If one party was native, the other foreign, the jury was to be half native, half foreign. Upon the judgment of the court execution was to be done in the manner provided for by the statute merchant. The statute contains various other enactments relating to the internal regulations of the staple.

Several other statutes were passed in the same and succeeding reigns, in some respects confirming, in others altering the provisions of the leading statute. As commerce became more extended, the staples appear to have fallen into disuse. Lord Coke, a great worshipper of antiquity, complains that in his time the staple had become a shadow; we have only now, he says, stapulam umbratilem, whereas it was formerly said that wealth followed the staple. The practice, however, of taking recognisances by statute staple, from the many advantages attending them, long continued. (11 Edw. I.; 27 Edw. III. caps. 1, 3, to 6, 8, 9; 2 *Inst.* 322; *Com. Dig.* tit. 'Stat. Staple;' 2 Saund. by Wms. 69; Reeves, *Hist. Eng. Law*, v. 2, pp. 161, 393.)

STAR, DOUBLE STAR. We distinguish the stars from the planets in much the same way as our ancestors did before us, though there is hardly one point of difference which is now left to its full extent. A contemporary of the publication of the 'Principia' (1687), engaged in writing an article like the present, would have stated that the only notion out of which antiquity described a star was derived from its fixedness in the heavens; to which he would have added that these stars present no appearance of systematic arrangement, that their distance is too great to be measured, and that they exert no sensible attraction on the solar system. Not one point of this is now left except the last: the speculation described in Milky Way gives a high probability to the theory that the universe is a collection of vast systems of stars; observations of double stars have rendered it certain that many organised systems, regulated by mutual attraction, exist in space, besides our solar system; it is fully established that numbers of stars, once called fixed, have slow motion of their own in the heavens; and in a few instances at least there is no room left for doubt that [Parallax of the Fixed Stars] the distance of the stars has been approximately ascertained. That no discoverable effect of attraction upon our system can be traced, is the only point in which the stellar astronomy of our own day coincides to the full extent with that of the time of Newton.

The apparent motions of the stars are first to be cleared of the effects of Precession and Nutation, and also of Aberration, which depend on motions of our earth, as well as of the grand diurnal revolution. From the Refraction of our atmosphere, and from the various casualties to which the rays of light are subject in passing through it, proceed, besides the increase of apparent altitude alluded to in the article cited, a great many varieties of colour and general appearance, particularly that decided size which most of the stars appear to have. A good telescope reduces this phenomenon very much, in favourable states of the atmosphere; but even these instruments are not so perfect as to show the stars to be what there is no doubt they ought to be, mere luminous points. If the apparent diameter of 61 Cygni, the earth's atmosphere being entirely removed, were only one-third of a second, or one-thirtieth of that of Venus when smallest, it is now known that the diameter of that star must be equal to that of the earth's orbit.

Independently of relative position, the stars are distinguished by their colour and quantity of light, on which last in a great degree depends their apparent magnitude. A casual observer would hardly think that there was any difference of colour between one and another; but a little practice shows that a tinge of one or another colour predominates a little in the nearly white light which all the stars have in common; and a good telescope gives some stars an appearance which observers have not scrupled to call "blood-red." And when the two stars of a close double star are together in the field of a telescope, it most frequently happens that each star differs sensibly in colour from the other. But when we look at a star, we must remember that we see only the result of the treatment which its light has received from the atmosphere; and with a telescope the matter is in some respects worse, for there is no object glass which forms anything like a real image. "When we look at a bright star," says Sir John Herschel, "through a very good telescope with a low magnifying power, its appearance is that of a condensed brilliant mass of light, of which it is impossible to discern the shape for the brightness; and which, let the goodness of the telescope be what it will, is seldom free from some small ragged appendages or rays. But when we apply a magnifying power from 200 to 300, the star is then seen (in favourable circumstances of tranquil atmosphere, uniform temperature, &c.) as a perfectly round well-defined planetary disc, surrounded by two, three, or more alternately dark and bright rings, which, if examined attentively, are seen to be slightly coloured at their borders. They succeed each other nearly at equal intervals round the central disc, and are usually much better seen, and more regularly and perfectly formed, in refracting than in reflecting telescopes. The central disc too is much larger in the former than in the latter description of telescope. These discs were first noticed by Sir William Herschel, who first applied sufficiently high magnifying powers to telescopes to render them visible. They are not the real bodies of the stars, which are infinitely too remote to be ever visible with any magnifiers we can apply; but *spurious* or unreal images, resulting from optical causes, which are still to a certain degree obscure." The various appearances of stars, as seen in telescopes, particularly the resolution of stars which appear single into two or more, render them excellent objects, when classified, for the examination of the power and goodness of these instruments. Such a classification was made by Sir J. Herschel ('Mem. Astron. Soc.'); and the paper is reprinted at the end of the explanation (published separately) of the maps of the stars published by the Society for the Diffusion of Useful Knowledge.

The magnitude of a star is a notion formed by observers as to the apparent quantity of light which comes from them, on which they are divided into classes. Those which are visible to the naked eye are usually divided into six magnitudes, which, according to W. Herschel, emit quantities of light which are (roughly) in about the proportions of the numbers 100, 25, 12, 6, 2, and 1. But though practical astronomers are tolerably well agreed as to the mode of naming most of the principal stars in respect of magnitude, there are many about which they differ, and some as to which it is tolerably well known that the order of magnitude which adherence to old catalogues still procures for them, is not that which would have been given had they been new stars named in our day. The magnitudes of stars are in fact rather indeterminate after the first and second. An astronomer would hardly say that an appearance was like a star of the "first or second" magnitude; the difference of the two is too well established, though as to the fainter stars of the first magnitude, and the brighter ones of the second, there may be little to choose between them. But it is very common to speak of an appearance as being of the "second or third," "third or fourth," &c., magnitude, showing that the distinction between one magnitude and the next is not then very prominent. Sir John Herschel and Professor Struve, the two most assiduous observers of small magnitudes, usually differ ('Mem. Astron. Soc.,' vol. iii. p. 180) about a magnitude in their estimation of one star with another, from and below Struve's fourth or Herschel's fifth magnitude, down to Struve's twelfth or Herschel's thirteenth. When therefore the reader, who is no astronomer, hears of the constant reference to stars of all magnitudes down to the sixteenth, he must look upon it as a rough mode of estimating the relative brilliancies of the stars, in which a numerical nomenclature is far from being held to imply numerical accuracy.

Some stars (perhaps all) are variable in their magnitudes, and with periodical regularity, which is perhaps to be attributed to the effect of revolution round their axes; it being imaginable that different parts of a star should give different kinds or quantities of light, either or both. [Variable Stars.]

There are a few instances in which a sudden appearance of a new star is recorded, followed, after a time, by its disappearance. Such a phenomenon made an astronomer, it is said, of Hipparchus; and certainly the star which appeared in Cassiopeia in 1572 was the introduction of Tycho Brahé to the character of a public astronomer. [Brahé, Tycho, in Biog. Div.] Tycho Brahé himself thought, from historical evidence, that a star had appeared in Cassiopeia in 945 and 1264, that of his own time being in 1572, from which, if the historical evidence be correct, a new star might be expected to appear in that constellation in 1872 or thereabouts. But, on examining his evidence, we find it exceedingly vague and deficient in antiquity. ('Comp. to Maps of the Stars,' p. 86.)

It has been reasonably supposed that those stars which have most motion are comparatively near to the earth, and when it was requisite to choose a double star for the determination of the question of Parallax, 61 Cygni was selected, as being a star with a large proper motion; in fact, its right ascension alters yearly 5″·46, and its declination 3″·19. The experiment turned out favourably, and the parallax was discovered, and with it (roughly) the distance of the star from the solar system. And though light takes more than ten years to travel from this star to the earth, at the rate of two hundred thousand miles a second; yet, so far from this being anything enormous, it rather cuts down the idea which was entertained of the distance of these bodies. The absence of all parallax, in spite of repeated efforts to obtain it, made many speculations upon the possibility of the nearest starlight being hundreds of years in reaching us. Among other stars which have a decided proper motion, we may notice Sirius, Procyon, 61 Virginis, α Bootis, A Ophiuchi, ρ Ophiuchi, and μ Cassiopeiæ.

The particular objects which are seen in the heavens are *stars*, simple points of light, and *nebulæ*, patches of an appearance of cloudy light. Single stars, under the telescope, very frequently become double, triple, quadruple, or even a large cluster; nebulæ are in some cases found to consist entirely of stars, but many remain which either are not composed of stars, or will not show themselves as such to the power of our present telescopes. It is necessary to say, in speaking of double stars, that they have been long known to exist, and that scores of observers have been diligently employed upon them during the last century and a half.

When two stars are so close together that the naked eye shows them only as one, it is possible that the coincidence may be merely optical; that is, that the lines of their directions may be so close as to make an apparent coincidence, such as takes place between the sun and moon in an eclipse of the former, though the real distances may be very great. Such optical coincidence is suspected in various double stars, but only a long course of observation can settle the suspicion in either way. But it is now found that many double stars are connected with each other by the law of gravitation, each revolving in an ellipse about their common centre of gravity, and showing every evidence of each being retained by the other, according to the Newtonian law of gravitation. The following stars, γ Leonis, ε Bootis, ζ Herculis, δ Serpentis, and γ Virginis, were made out to be revolving double stars, by W. Herschel, in 1803. He had been examining these pairs under the idea of detecting the parallax from them, and in so doing he recognised their changes of relative position. Since that time, Castor, ξ Ursæ, 70 Ophiuchi, σ Coronæ, η Coronæ, ξ Bootis, η Cassiopeiæ, δ Cygni, μ Bootis, ε (4) and ε (5) Lyræ, λ Ophiuci, μ Draconis, ζ Aquarii, ζ Cancri, and others, have been added to the list. The periods of revolution of several have been determined, ranging from 43 to 1200 years, and the other elements of several orbits have been established. The star η Coronæ has completed a revolution since it was first observed.

The most interesting of double stars is γ Virginis. When observed by Herschel in 1780, the distance between the two constituent stars amounted to 5″·66. Henceforward it continued gradually to decrease, until at length, in 1836, the two stars had approached so close as to appear like one star even when observed in the best telescopes. From that time the two stars have been slowly opening out from each other, until they are now nearly 4″ apart. The orbit of this double star has been computed by several astronomers, including among these Sir John Herschel, who has found the period of revolution to be 182 years. The orbits of a considerable number of double stars have been computed in recent years, a list of which will be found in Herschel's 'Outlines of Astronomy' and other similar works. The most distinguished observers of double stars besides the elder Herschel have been Sir John Herschel, Sir James South, the Rev. Mr. Dawes, and Admiral Smyth, in this country; and on the continent the elder Struve, Bessel, Professor Mädler, Otto Struve and Professor Secchi. The labours of the elder Struve in this field of astronomical observation exceed in magnitude and importance those of any other astronomer.

STAR-CHAMBER. The Star-Chamber is said to have been in early times one of the apartments of the king's palace at Westminster allotted for the despatch of public business. The Painted Chamber, the White Chamber, and the Chambre Markolph, were occupied by the triers and receivers of petitions, and the king's council held its sittings in the Camera Stellata, or Chambre des Estoylles, which was so called probably from some remarkable feature in its architecture or embellishment. According to Sir Thomas Smith's conjecture "either because it was full of windows, or because at the first all the roofe thereof was decked with images or starres gilded." ('Commonwealth of England,' book iii. cap. 4.) Sir William Blackstone proposes a conjecture that the chamber received its name from its having been a place of deposit for the contracts of the Jews, called "Itarrs," under an ordinance of Richard I. (Blackstone's 'Commentaries,' vol. iv. p. 266, note.) Whatever may be the etymology of the term, there can be little doubt that the court of Star-Chamber derived its name from the place in which it was holden. "The lords sitting in the Star-Chamber" is used as a well-known phrase in records of the time of Edward III., and the name became permanently attached to the jurisdiction, and continued long after the local situation of the court was changed.

The judicature of the court of Star-Chamber appears to have originated in the exercise of a criminal and civil jurisdiction by the king's council, or by that section of it which Lord Hale calls the *Consilium Ordinarium*, in order to distinguish it from the *Privy Council*, who were the deliberative advisers of the crown. (Hale's 'Jurisdiction of the Lords' House,' chap. v.; Palgrave's 'Essay on the Original Authority of the King's Council.') This exercise of jurisdiction by the king's council was considered as an encroachment upon the common law, and being the subject of frequent complaint by the Commons, was greatly abridged by several acts of parliament in the reign of Edward III. It was discouraged also by the common-law judges, although they were usually members of the council; and from the joint operation of these and some other causes the power of the Consilium Regis as a court of justice had materially declined previously to the reign of Henry VII., although, as Lord Hale observes, there remain "some straggling footsteps of their proceeding" till near that time. The statute of the 3 Henry VII. c. 1, empowered the chancellor, treasurer, and keeper of the privy-seal, or any two of them, calling to them a bishop and temporal lord of the council and the two chief justices, or two other justices in their absence (to whom the president of the council was added by stat. 21 Henry VIII., c. 20), upon bill or information exhibited to the lord chancellor or any other, against any person for maintenance, giving of liveries, and retainers by indentures or promises, or other embraceries, untrue demeanings of sheriffs in making panels and other untrue returns, for taking of money by juries, or for great riots or unlawful assemblies, to call the offenders before them and examine them, and punish them according to their demerits. The object and effect of this enactment are extremely doubtful. It appears to have been the opinion of the courts of law at the time the statute was passed that it established a new jurisdiction, entirely distinct from the ordinary jurisdiction of the council; for five years afterwards, in the eighth year of Henry VII., it was resolved by all the judges, according to the plain words of the law, that the only judges of the court under the statute were the lord chancellor, the treasurer, and the keeper of the privy-seal, the bishop and temporal lord being merely "called to them" as assistants or assessors, and not as constituent members of the court. ('Year Book,' 8 Hen. VII., 13, pl. 7.) This view of the effect of the statute is confirmed by the fact that, more than forty years afterwards, the president of the council was expressly added to the judges of the court by the statute 21 Henry VIII., c. 20; "a decisive proof," as Mr. Hallam observes "that it then existed as a tribunal perfectly distinct from the council itself." ('Constitutional History,' vol. i., p. 70.) And this writer concludes a careful examination of the subject by the following propositions: "1. The court erected by the statute of 3 Henry VII. was not the court of Star-Chamber, 2. This court by statute subsisted in full force till beyond the middle of Henry VIII.'s reign, but not long afterwards went into disuse. 3. The court of Star-Chamber was the old *Concilium Ordinarium*, against whose jurisdiction many statutes had been enacted from the time of Edward III. 4. No part of the jurisdiction exercised by the Star-Chamber could be maintained on the authority of the statute of Henry VII." In the first of these propositions, Mr. Hallam is confirmed by Hudson, in his 'Treatise of the Court of Star-Chamber.' ('Collectanea Juridica,' vol. ii. p. 50.) On the other hand, both Lord Coke and Lord Hale consider the statute of Henry VII. as having merely introduced a modification of the ancient jurisdiction. The former calls the above resolution of the common-law judges "a sudden opinion," and says it is "contrary to law and continual experience." And he contends that the statute did not create a new court, but was merely declaratory of the mode of proceeding in an ancient court, previously known and recognised. ('Fourth Institute,' p. 62.) Lord Hale also speaks of the "erection of the court of Star-Chamber by the stat. 3 Henry VII.," and says it "was a kind of remodelling of the *Consilium Regis*." ('Jurisdiction of the Lords' House,' chap. v., p. 35.) However this may have been, there is no doubt that, previously to the time of Coke, this court, whether distinct or only a modification of the ancient jurisdiction, had again merged in the general jurisdiction of the lords of the council so completely as to justify his statement, that the opinion expressed in the judicial resolution was "contrary to continual experience." Sir Thomas Smith, who wrote his 'Treatise on the Commonwealth of England' in the year 1565, makes no mention of a limited court, though he treats particularly of the court of Star-Chamber, and says that the judges were the lord chancellor, the lord treasurer, all the king's council, and all peers of the realm; and he ascribes the merit of having renewed the vigour of the court to Cardinal Wolsey. At the beginning of the reign of Elizabeth, therefore, the court of Star-Chamber was unquestionably in full operation in the form in which it was known in the succeeding reigns; and at this period, before it had degenerated into a mere engine of state, it was by no means destitute of utility. It was the only court in the land in which great and powerful offenders had no means of setting at defiance the administration of justice or corrupting its course. And during the reign of Elizabeth, when the jurisdiction of the Star-Chamber had reached its maturity, it seems, except in political cases, to have been administered with wisdom and discretion. (Palgrave's 'Essay on the King's Council.')

The proceedings in the court of Star-Chamber were by information, or bill and answer; interrogatories in writing were also exhibited to the defendant and witnesses, which were answered on oath. The attorney-general had the power of exhibiting ex-officio informations; as had also the king's almoner to recover deodands and goods of a felo-de-se, which were supposed to go in support of the king's alms. In cases of confession by accused persons, the information and proceedings were oral, and hence arose one of the most oppressive abuses of the court in political prosecutions. The proceeding by written information and interrogatories was tedious and troublesome, often involving much nicety in pleading, and always requiring a degree of precision in setting forth the accusation which was embarrassing in a state prosecution. It was with a view to these difficulties that Lord Bacon discouraged the king from adopting this mode of proceeding in the matter of the pursuivants, saying that "the Star-Chamber without confession was long seas." (Bacon's 'Works,' vol. iii. p. 372.) In political charges, therefore, the attorney-general derived a great advantage over the accused by proceeding *ore tenus*. The consequence was, that no pains were spared to procure confessions, and pressure of every kind, including torture, was unscrupulously applied. According to the laws of the court, no person could be orally charged, unless he acknowledged his confession at the bar, "freely and voluntarily, without constraint." (Hudson's 'Treatise of the Court of Star-Chamber.') But this check upon confessions improperly obtained seems to have been much neglected in practice during the later periods of the history of this court. Upon admissions of immaterial circumstances thus aggravated and distorted into confessions of guilt, the Earl of Northumberland was prosecuted *ore tenus* in the Star-Chamber, for being privy to the Gunpowder Plot, and was sentenced to pay a fine of 30,000*l.* and to be imprisoned for life; "but by what rule," says Hudson ('Coll. Jurid.,' vol. ii.), "that sentence was, I know not, for it was *ore tenus*, and yet not upon confession." And it frequently happened during the last century of the existence of the Star-Chamber, that enormous fines, imprisonments for life or during the king's pleasure, banishment, mutilation, and every variation of punishment short of death, were inflicted by a court composed of members of the king's council, upon a mere oral proceeding, without hearing the accused, without a written charge or record of any kind, and without appeal.

The judges of the court of Star-Chamber were the lord chancellor or lord keeper, who presided, and when the voices were equal gave a casting vote, the lord treasurer, the lord privy seal, and the president of the council, who were members of the court *ex officio*, probably by usage since the statute of 3 Henry VII. In addition to these, were associated, in early periods of the history of the court, any peers of the realm who chose to attend. According to Sir Thomas Smith, the judges in his time were the "lord chancellor, the lord treasurer, all the king's majesty's council, and the barons of this land." ('Commonwealth of England,' b. iii. c. 5.) Hudson states that the number of attendant judges "in the reigns of Henry VII. and Henry VIII. have been well near to forty; at some one time thirty; in the reign of Queen Elizabeth often times, but now (that is, in the time of James I.) much lessened, since the barons and earls, not being privy councillors, have forborne their attendance." He further states, that "in the times of Henry VII. and Henry VIII. the court was most commonly frequented by seven or eight bishops and prelates every sitting-day;" and adds, "that in those times, the fines trenched not to the destruction of the offender's estate, and utter ruin of him and his prosperity, as now they do, but to his correction and amendment, the clergy's song being of mercy." ('Coll. Jurid.,' vol. ii., p. 36.) The settled course during the latter part of the reign of Elizabeth and the reigns of James I. and Charles I. seems to have been to admit only such peers as judges of the court as were members of the privy council.

The civil jurisdiction of the Star-Chamber comprehended mercantile controversies between English and foreign merchants, testamentary causes, and differences between the heads and commonalty of corporations, both lay and spiritual. The court also disposed of the claims of the king's almoner to deodands, as above referred to, and also such claims as were made by subjects to deodands and *catalla felonum* by virtue of charters from the crown. The criminal jurisdiction of the court was very extensive. If the king chose to remit the capital punishment, the court had jurisdiction to punish as crimes even treason, murder, and felony. Under the comprehensive name of contempts of the king's authority, all offences against the state were included. Forgery, perjury, riots, maintenance, embracery, fraud, libels, conspiracy, and false accusation, misconduct by judges, justices of the peace, sheriffs, jurors, and other persons connected with the administration of justice, were all punishable in the Star-Chamber.

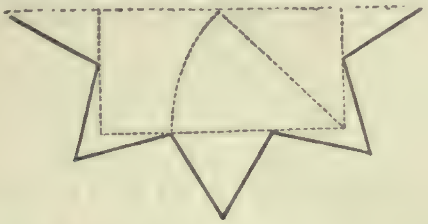
It was also usual for the judges of assize previously to their circuits to repair to the Star-Chamber, and there to receive from the court directions respecting the enforcement or restraint of penal laws. Numerous instances of this unwarrantable interference with the administration of the criminal law occur with reference to the statutes against recusants in the reigns of Elizabeth and James I.

A court of criminal judicature, composed of the immediate agents of prerogative, possessing a jurisdiction very extensive, and at the same time imperfectly defined, and authorised to inflict any amount of punishment short of death, must, even when best administered, have always been viewed with apprehension and distrust; and, accordingly, in the earlier periods of its history we find constant remonstrances by the Commons against its encroachments. As civilisation, knowledge, and power increased among the people, the jurisdiction of the lords of the council became more odious and intolerable. A measure which was introduced into the House of Commons in the last parliament of Charles I., to limit and regulate the authority of this court, terminated in a proposal for its entire abolition, which was eventually adopted without opposition in both houses. The statute 16 Car. I. c. 10, after reciting Magna Charta and several early statutes in support of the ordinary system of judicature by the common law, goes on to state that "the judges of the Star-Chamber had not kept themselves within the points limited by the statute 3 Henry VII., but had undertaken to punish where no law warranted, and to make decrees having no such authority, and to inflict heavier punishments than by any law was warranted; and that the proceedings, censures, and decrees of that court had by experience been found to be an intolerable burthen to the subjects, and the means to introduce an arbitrary power and government." The statute then enacts, "that the said court called the Star-Chamber, and all jurisdiction, power, and authority belonging unto or exercised in the same court, or by any of the judges, officers, or ministers thereof, should be clearly and absolutely dissolved, taken away, and determined, and that all statutes giving such jurisdiction should be repealed."

STAR-FORT, a kind of redout inclosing an area, and having its lines of rampart or parapet disposed, on the plan, in directions making with each other angles which are alternately salient and re-entering, as a star is usually represented. This construction is adopted when the work is intended to contain, for some time, the stores of an army, or to secure some important part of the position which the army occupies. The magistral line of the work may be traced by first laying down a polygonal figure, regular or irregular, as the ground may permit, and then upon each of its sides forming an equilateral triangle: the interior capacity and the quantity of fire will evidently be increased as the polygon has a greater number of sides; but the importance of the work is seldom so great as to render it necessary to form it on a polygon superior to a hexagon or an octagon; and the latter polygon, while it admits of being easily traced, allows the re-entering angles between the sides of the triangles to have a degree of obtuseness sufficient to avoid the risk that the defenders of the faces on each side of such an angle might fire upon one another. As it is found that soldiers fire nearly perpendicularly to the face of the parapet behind which they stand, a greater obtuseness would cause the lines of fire to diverge so far from the direction of the adjacent face as to prevent the ditch of the latter from being effectually flanked.

A star-fort on an octagon may, if the ground is level, be traced by laying down a square, and, upon the middle of each of its sides, an equilateral triangle, whose base is one-third of the length of such side; or, more regularly, by transferring half the diagonal of the square to each side, from the four angles; the distances between the extremities of these half diagonals are the sides of an equilateral octagon, and upon these sides equilateral triangles may be formed. The subjoined cut represents the magistral line of half a star-fort with eight points, constructed in this last manner. If the polygon had more than twelve sides, the re-entering angles would be acute; and, agreeably to the above supposition concerning the direction in which soldiers fire, the defenders on the adjacent faces might annoy one another.

That the fire of musketry may be sufficiently effective, it is considered proper that the lengths of the several faces should not be less than thirty yards; and a star-fort whose faces are of much greater length is capable of containing a garrison more numerous than that which would be required for the end proposed by such a work. A star-fort with six or eight points has a great advantage over a simple redout, though its construction is less simple: the crossing fires from the faces seriously impede the advance of the enemy towards the salient points; and the assailants, in passing the ditch, are completely exposed to the view of the defenders.



During the Seven Years' War, the king of Prussia's intrenched camp at Jauernick contained a star-fort on a rising ground in its centre, from whence the movements of the Austrians could be observed; and in this work the king's tent was pitched. The position taken up on the Nivelle by Marshal Soult, while the British army was acting in the south of France (1813), was protected by a strong star-fort. The work was constructed on a terrace below the summit of a mountain called the Smaller Rhune, and was intended to defend the entrance of a ravine. A platform below the summit of a ridge of high ground near the Bidassoa was, in like manner, fortified by a star-fort.

STARCH ($C_{12}H_{10}O_{10}$). *Fecula; Amidon; Amylaceous matter.*—The substance known in commerce and in domestic life as starch, is usually prepared from wheaten flour. *Starch*, however, exists in abundance in very many other vegetables, so that, strictly speaking, the term is a generic one. The flour of barley, oats, rye, arrow-root, sago, tapioca, rice; the greater part of the common potato, harico bean, lentil, maize, millet, &c., is starch. The starch from these various sources is identical so far as composition is concerned; the elements carbon, hydrogen, and oxygen exist in exactly similar proportions in all. As usually met with, the several varieties differ somewhat in taste, but this is probably owing to admixture of traces of volatile oil. [ESSENTIAL OILS, *of Starch.*] They appear also to slightly differ from each other in capability of assimilation when taken as food; a fact not yet satisfactorily accounted for.

To the naked eye starch presents a white glistening appearance, and seems to be an aggregation of small shapeless particles. By the aid of the microscope, however, it is seen to consist of beautiful regular ovoid granules; and under a magnifying power of from two to five hundred diameters, each granule is found to be marked by a series of circles converging from the circumference to a point termed the hilum. The size of the granule, the distinctness of the concentric lines, and the position of the hilum, are always the same in any one kind of starch, but vary considerably in starch from various sources; the microscope is therefore of considerable aid in detecting the admixture of an inferior with a superior variety, and in determining the origin of a starch.

Starch is insoluble in, and but very slightly acted upon by, cold water; nor is it really soluble in hot water. When, however, it is heated with twenty or thirty times its weight of water its granules swell and finally burst; if the whole be diluted and set aside, the rent walls of the granules subside to the bottom of the containing vessel, while their contents are so thoroughly mixed with the water that the two can only be separated by very tedious processes. Starch is also insoluble in alcohol or ether. Acids and alkalies, even when cold and highly diluted, cause it to swell and form a paste and finally convert it into dextrin. Air-dried starch usually contains about eighteen per cent. of water; if more than this is present the starch has a tendency to agglutinate when pressed between the finger and thumb; moreover, when projected on to a metal plate heated to 212° Fahr., it agglomerates into hard lumps forming a sort of artificial tapioca, no such effect being produced if it has been properly air-dried. Exposed in vacuo at a temperature of 60° Fahr., the amount of water is reduced to fifteen per cent. ($C_{12}H_{10}O_{10}$, 2Aq.) and at 260° Fahr. to the minimum of eight and a half per cent. ($C_{12}H_{10}O_{10}$). At a higher heat than this, starch is converted into dextrin.

Starch combines with certain bases, the compounds have been termed *amylates;* that of lead contains ($C_{12}H_9O_9 + 2PbO$).

Test for Starch.—Free iodine communicates a deep blue colour to starch. The resulting body is called iodide of starch, but its constitution has not yet been satisfactorily ascertained. The colour disappears if the iodine be in excess, if the mixture be boiled, or if any unstable organic matter, such as urine, be added to it. By bringing iodide of starch into contact with yeast, M. Duroy has lately obtained what he calls colourless iodide of starch, a sweet, gummy, uncrystallisable neutral substance, very soluble in water, but insoluble in alcohol.

The amount of starch in various vegetables varies as they progress towards maturity, and is much influenced by soil and climate.

		Per cent.			Per cent.
Wheat . .	contains about	60	Beans . .	contains about	37
Potatoes . .	,,	20	Peas . . .	,,	38
Rice . .	,,	83	Buckwheat . .	,,	44
Rye . . .	,,	60	Indian corn . .	,,	66
Oats . .	,,	37	Horse-chestnut	,,	25
Barley . . .	,,	64	Arrowroot tuber	,,	20

Wheat Starch.—Wheaten flour is mixed with water and exposed to the air, with occasional stirring, for several weeks. During this time a portion of the gluten of the flour undergoes putrefaction: fermentation is set up, and some of the starch is converted into carbonic acid and alcohol, acetic and lactic acids are also formed. During this change an exceedingly unpleasant prutrescent odour is given off from the mass; the starch, however, ultimately subsides in the pure state, and colourless, the other matters with which it was mixed in the flour, as well as some products of decomposition, remaining in solution or floating on the surface as a scum, called *slimes* or *flummery*. The latter was formerly given to pigs for food, but is now used by the calico-printer as a resist paste. The peculiar, but well-known columnar appearance of wheat starch, as met with in commerce, is acquired during the drying opertion. The moist starch is cut up into blocks about six inches square, and placed in carefully heated stoves; as the water evaporates the masses shrink and split up into the characteristic irregular fragments.

A preferable method of extracting starch from wheat-flour has lately been introduced by Mr. Martin. It consists in kneading the flour into dough with water, and then washing on a sieve in a stream of water. The starch is thus washed out, and nearly all the gluten remains behind as a sticky mass. Slight fermentation is induced in the washings, whereby the remaining portions of gluten are destroyed, and the starch is then dried. The gum-like gluten educed in this process is dried, ground, and sold as semolina, or is mixed with flour and made into maccaroni and similar pastes.

Potato Starch, now largely manufactured on the Continent, is readily obtained from the washed and rasped or grated potatoes by simple kneading of the pulp in a stream of water on an inclined plate or fine sieve; the starch is carried off by the water, is allowed to subside, and after one or two washings by decantation, is drained in boxes lined with felt, and dried on floors of plaster of Paris. Potato starch does not, in drying, assume the columnar form characteristic of wheat starch.

Rice Starch.—For the preparation of this variety the rice is macerated for twenty-four hours in a very weak alkaline solution, composed of nearly half an ounce of caustic soda to a gallon of water; it is then washed, drained, reduced to a pulp, and again macerated in a fresh quantity of soda-ley; after brisk agitation and a short repose the liquor, still containing the starch in suspension, is poured off from the vegetable fibre, which first deposits, and the starch, accumulated by subsidence, is finally dried in the usual manner. The object of this process is the solution of the gluten in the weak alkali. If the latter be carefully neutralised by sulphuric acid the gluten is deposited in flocks, and after washing may be used in the preparation of certain varieties of food, as before mentioned.

Other Materials for Starch.—Mr. Simmonds states that at Oswego, in New York State, starch is made on a vast scale from maize or Indian corn. There is one factory which covers nearly three acres, and which consumes 200,000 bushels of maize yearly, whence is obtained 4,000,000 lbs. of starch. Mr. Anderson, by a patent obtained in 1857, proposes so to treat maize as to obtain starch from one portion, and oil from a residue hitherto wasted. Frequent search is made for new materials whence starch may be obtained. So far back as 1796, the Society of Arts offered a prize medal for any novelties in this direction. The prize was awarded to Mrs. Gibbs of Portland, who obtained starch from the roots of the *Arum maculatum*—4 lb. from 1 peck. It was very pure, and was sold under the name of "Portland arrow-root." There is not much now made, because the rotation of crops prevents the wild arum from growing. In 1853, M. Bassot obtained a prize in France, for making starch from the *Fistillaria imperialis*, or *crown imperial;* he washes and rasps the bulbs, and obtains starch from them in the usual way. The plant grows well in France. M. Bassot estimates that 5000 lbs. of starch may come from an acre of land, and need not cost more than 4*s.* per cwt.—much cheaper than potato starch. In 1857, there was a great demand for horse-chestnuts in France, in consequence of the establishment of a factory at Nanterre for making starch from that source. Chestnut trees are very abundant in France, and the starch obtained from the fruit is said to be good.

The use of starch in the cotton manufacturing districts is very large. One print-work in Manchester consumed 6000 cwts. in 1859 A kind called *Glenfield* starch is, by a peculiar process, made semi-transparent, for use in stiffening net and lace.

Properties of Starch.—Starch, when pure, is nearly devoid of odour and taste, and is possessed of demulcent properties when boiled in water, with which it forms a hydrate of a jelly-like character. Its insipidity, however, hinders it from being very digestible in this state, or even when kneaded with cold water, and exposed to heat, to form biscuits. Its digestibility is greatly increased by fermentation, and hence bread or rusks are much more suitable to invalids than any unfermented preparations of flour. The best bread is formed by flour which contains the greatest proportion of gluten. The relative proportions of starch and gluten differ not only in the different cereal grains, but in the same species or variety, according to the season when they are sown, or the manure which has been applied to the land.

Starch exists in larger proportion in Carolina rice than in any other grain. Potatoes yield the purest starch. It is procured from them with great ease, by simply rasping down the potatoes over a sieve, and passing a current of water over the raspings. The water passes through the sieve milky with the starch. By rest the starch subsides; it is then two or three times washed with pure water, and afterwards allowed to dry.

The quantity of starch is at its maximum in the winter months, but as soon as the potato begins to sprout, the starch lessens, as does also the proportion of nitrogen, so that its nutritive properties are impaired. If, however, the process of isolating the starch be followed in the winter months, the result is, a sixth portion of the weight of the potatoes employed, in a condition fit not only for immediate use, but of easy transport, and capable of preservation for years.

Starches differ, according to their sources, in chemical composition, and certainly in their digestibility, as also in their nutritive properties, according as they are isolated or associated with other principles, such as gluten. Wheat-starch consists of $C_{12}H_{10}O_{10}$, while potato-starch consists of $C_{12}H_9O_9$. Arrowroot has no gluten associated with it, rice very little, potato only one-third what good wheat has. Thus while arrowroot is the most digestible, wheat is the most nourishing. Potatoes are neither nourishing nor digestible, being of all starches the most prone to run into acidity, and so distress weak stomachs. The consumers of rice and potatoes are remarked to be almost invariably pot-bellied, owing to the large quantity they are compelled to use. "To supply a given amount of carbon and nitrogen to the system it costs two and a half times as much to obtain it from potato as from bread." (Dr. Edward Smith.) These facts constitute a strong objection to the use of potatoes, either in their natural state, as when used at dinner, or when employed as a constituent of bread. Many persons have found their health strikingly improved by relinquishing the use of potatoes. It is difficult to detect the presence of potato-starch in bread. The motive for using it is that it takes up more water than wheat-flour. But this is a double disadvantage to the consumer, as he gets less nutritious material for his money, and has unhealthy acid generated in his stomach. The bread made with flour very moist is always inferior, from an alteration in the gluten, unfavourable to a perfect panification, and because such bread is very much more prone to become mouldy, by which its degree of wholesomeness is still farther impaired. (Dumas, 'Traité de Chimie appliqué aux Arts,' vol. vi. p. 391.)

The carefully devised and systematically conducted experiments of Dr. Edward Smith prove that "animals cannot live on starch, and yet it is not uncommon to find mothers with deficient milk giving to their infants arrowroot, or some of the fashionable preparations of corn, which consist almost entirely of starch freed from the important nitrogenous constituents, and using water instead of cow's milk, under the impression that the latter would be too rich a food. Such a course can only be a source of starvation," and a fertile source of mortality. (See 'Practical Deductions from an Experimental Inquiry into the Influence of Foods,' by Edward Smith, M.D., Dublin, 1860.)

The above are the more important kinds of starch. For information concerning starch from other sources see the names of the several plants in the NATURAL HISTORY DIVISION of this Cyclopædia. [ARROWROOT; SAGO; SALEP; TAPIOCA.]

STARCH GUM. [BRITISH GUM.]

STARS, DOUBLE. [STAR, &c.]

STARS, SHOOTING. [METEOR.]

STATE. [SOVEREIGNTY.]

STATER (*στατήρ, a standard* of value), or *Chrysus* (*χρυσοῦς, gold money*), was the name of a Greek gold coin, which, after being used from a very early period in some states, became, in the time of Philip II. and Alexander the Great, the general gold currency of Greece. It is said to have been first coined in Lydia, to which the origin of silver money also is attributed by an ancient tradition. (Herod. i. 94.) The stater of Crœsus seems to have been the first gold money seen in Greece. (Herod. i. 54.) No undoubted specimen of this Lydian stater is in existence. According to Böckh, it was formed of the pale gold or electrum (¾ gold and ¼ silver) contained in the sands of the Pactolus.

Of the better known gold coins, most were of the same standard of weight as the Attic drachma, the Attic silver having at a very early period obtained a general circulation throughout Greece, and being reckoned extremely pure. The stater was generally equal in weight to two drachmæ, and in value to twenty. This was the case with the Macedonian stater, which the influence of Philip and Alexander brought into general circulation in Greece, and which continued to be coined by the later Macedonian kings after the same standard, or very nearly so. Many specimens of it exist.

The average weight of the staters of Philip and Alexander is a little under 133 grains. An assay of a stater of Alexander, made for Mr. Hussey, gave 115 grains of fine gold and 18 of silver, with no alloy. The silver here ought not to be reckoned as an alloy, and therefore the coin is equivalent to 133 grains of fine gold. Our sovereign contains 113·12 grains of fine gold. Therefore this stater was worth $\frac{133}{113{\cdot}12}$ of a sovereign, or a very little more than 1*l.* 3*s.* 6*d.* If we calculate its value by the number of drachmæ it was worth, we find it only 16*s.* 3*d.* The reason of this is, that silver was much dearer in ancient times than it is now. The higher value of the stater is the true one, as no material change has occurred in the value of gold.

In the states of Greece proper the chief standards of money followed were those of Athens and Ægina. In both, the principal denominations of money were coined in silver, and it does not appear that the Æginetan system contained any gold coin.

At Athens there seems to have been no gold money in the flourishing times of the republic, if we except a coinage mentioned by the Scholiast to Aristophanes ('Frogs,' v. 719). There are however a few Attic gold coins in existence, but only about a dozen. Of these, three, which there is every reason to suppose genuine, are in the British Museum, and one in the Hunterian Museum at Glasgow. Their weights agree exactly with the Attic standard, being respectively 132·3, 132·7, 132·6, and 132·75 grains, or on the average 132·5875 grains, which is only about half a grain less than the Attic didrachm. The character of the impression is exactly like that of the old Attic silver, but the form of the coin is more like the Macedonian.

It is very clear however that foreign gold was in circulation at Athens quite as early as the Peloponnesian war. It was obtained doubtless in commerce, and as the tribute of the allies, many of whom had gold currencies. Among the denominations so used, the chief were the darics of Persia [DARIC] and the staters of the Greek cities of Asia and the neighbouring islands. In fact, the Greeks got nearly all their gold from Asia. The following were the principal coins of Greek states in circulation at Athens:—

Demosthenes (in 'Phorm.,' p. 914, Reiske) informs us that a little after 335 B.C. the stater of Cyzicus passed at Bosporus in the Tauric Chersonese for twenty-eight Attic drachmæ. The existing coins vary from 160 to 120 grains, the former of which is greater, the latter less than the Attic, and both apparently derived from an element of 40 grains. The existing coins seem however to have been multiples of different standards. As the heaviest of the existing coins does not come up to the weight answering to the value assigned to the Cyzicene stater by Demosthenes, we must suppose that gold was dearer or silver cheaper than usual at Bosporus at the time referred to.

The *Staters of Lampsacus*, which may be recognised by the impression of a sea-horse, are of the standard of the daric. Two in the British Museum weigh about 129 grains each.

The *Stater of Phocæa* also appears, from the specimens given by Sestini ('Degli Stateri Antichi'), to have followed the standard of the daric. It was divided into sixths (*ἕκται*) and twelfths (*ἡμίεκτα*), of which the latter were equal in value to eight obols, and in weight probably to one, since the obol bore the same proportion to the didrachm in the silver coinage, that the *ἡμίεκτον* did to the stater in the gold.

Most of the cities of Ionia coined staters. Those of Chios, Teos, Colophon, Smyrna, Ephesus, and other places, now exist. There were also gold coins struck in Samos, Siphnus, Thasos, the Greek cities of Sicily, and Cyrene, at an early period. After the Macedonian coinage of staters, many Greek states coined them according to the same standard; we may mention Epirus, Acarnania, Ætolia, and Syracuse.

The coins in the system of the stater were the single, double, and half staters; these were very common: there were also, less commonly, quarters, thirds, sixths, and twelfths of staters.

The Attic silver tetradrachm was called stater in later times, but it is doubtful whether it was so called in the best ages of the republic.

The term stater was also applied to weight, meaning apparently any standard of weight. The Mina and Sicilian Litra were so called.

(Hussey, *Ancient Weights and Money*; Wurm, *De Pond.*, &c.; Böckh, *Metrologische Untersuchungen*; Humphrey, *Coin Collector's Manual.*)

STATES-GENERAL. [NATIONAL ASSEMBLY.]

STATICS, a subdivision of mechanics, meaning the part of the science in which equilibrating forces are considered, in opposition to DYNAMICS, in which the effects of forces producing motion are investigated: it is subdivided into the statics of rigid and of fluid bodies, the latter being called HYDROSTATICS. The general considerations in MECHANICS, FORCE, PRESSURE, POWER, WEIGHT, &c., and such articles as LEVER, INCLINED PLANE, PULLEY, WHEEL AND AXLE, WEDGE, SCREW, may be consulted; and also the articles VIRTUAL VELOCITIES, THEORY OF COUPLES, &c.

One foundation of statics was first given by Archimedes, and another by Stevinus, as noticed in MECHANICS. The former is the more rigorous, the latter being open to some objections of a serious character. The discoveries of Galileo turned the attention of philosophers upon dynamical problems, and the very easy connection which exists between the statical and dynamical measure of forces caused the theory of statics to be founded, almost up to the present day, upon dynamical principles. The taste for the purer form of statics has however revived, and we imagine that from henceforward it will be customary to make this science stand by itself.

The two great propositions of statics are that of the LEVER, demonstrated in the article on that word, and that of the COMPOSITION of pressures, mentioned, but not demonstrated. Which of these shall be chosen as the foundation of the science, and how the other shall be deduced from it, are two points on which every writer on the subject should think much, as the character of his work in the eyes of others will, in a great measure, depend on his treatment of these parts of the subject. The method of Archimedes is, in our opinion, the soundest of all; but we say it without denying the possibility of exhibiting a direct statical proof of the composition of pressures which shall be equally satisfactory. In those which have hitherto been given, there is a want of distinction between the mathematical and physical assumptions: the student leaves off with no very clear perception how far the proposition is one of mathematics, and how far one of physics. There is a general dislike and distrust of these proofs, which is evidence almost conclusive against them: any one who would improve them should not leave off until he has not only made a better separation of the physical axioms from the rest, but has put it in a form in which such separation is exceedingly obvious. Till this is done, the proofs in question will only stifle opposition, while the proposition of Archimedes forces conviction. If there be anything likely to be misunderstood in the latter, it applies as much to the former in all the cases which we have seen. [SUFFICIENT REASON.]

Statics, like all other mechanical sciences, is usually placed among mixed MATHEMATICS. But the line which separates it from the pure sciences is almost imperceptible, and it would seem more reasonable to invent a third and intermediate distinctive term, than to place statics and electricity under the same name, to distinguish them from geometry. It would be easy to show that all which is common to geometry and statics, and not to electricity, is more extensive, more striking, and more easily described, than the little which is common to statics and electricity, and not to geometry. In fact, when we say that both statics and electricity are concerned with properties of matter as distinguished from space, we have stated the whole of the common tie by which the two sciences are united: while geometry and statics possess in common almost equal degrees of evidence in their axioms, altogether the same rigour of deduction, and strong analogies in their theorems. Mr. Whewell has contended for the alteration of the location of statics: but he carries the idea farther than we can follow him, for ('Mechanical Euclid,') he asserts that the axioms of statics are "self-evidently true," "not to be learnt from without, but from within." We may also refer to the same writer's 'History of Scientific Ideas,' vol. i., 1858. We shall enter further upon this point in the article SUFFICIENT REASON.

STATIONARY (Astronomy). All the planets appear at the earth to move alternately forwards and backwards in the heavens, the retrograde motion not continuing so long as the direct motion. For a little time at the beginning and end of the retrogradation, the planet appears to have no motion. This arises when the relative MOTION of the planet is really towards the earth. The planet's velocity may always be decomposed into two, one in the direction of the earth's motion, or its opposite, the other towards or from the earth. When it happens that the former motion is not only parallel to that of the earth, but equal to it, the planet cannot change its place in the heavens, but all its apparent motion is the remaining motion, directly to or from the earth. If the planet were so near that we could readily see alterations of its distance, we should say it was directly approaching or receding: but as we cannot see this phenomenon, we pronounce it stationary, and for some nights we lose the distinction between it and the fixed stars. [TROCHOIDAL CURVES.]

STATIONARY. This term requires introduction into mechanics in a manner corrective of the mistakes which have sometimes been made. One of these is pointed out in STABLE AND UNSTABLE. Instead of saying that a system acted on by its weight is in equilibrium only when the centre of gravity is highest or lowest, it is there pointed out that all that is necessary is that the motion which the centre tends to take should be horizontal: or that the centre should be *stationary* as to ascent or descent, for the moment. Again, there is what is called the *principle of least action* [VIRTUAL VELOCITIES], which the mathematician will recognise in the theorem that the motion of a system is always such that $\Sigma m \int v\, ds$ is a minimum. Now all that is proved is that in the motion of a system, in the language of the calculus of VARIATIONS, $\delta \Sigma m \int v\, ds$ is $= 0$. Now all that this requires is that $\Sigma m \int v\, ds$ should be *stationary*; or that if a path infinitely near the path of motion should be chosen, $\Sigma m \int v\, ds$, calculated for the new path, should differ from the same calculated for the old path, by a quantity of an order inferior to those on which the difference of the paths depends. Sir W. Hamilton proposes to call this the principle of *stationary* action, instead of that of least action; the action of a particle whose mass is m moving over an arc s being a name given to $m \int v\, ds$, taken from one end of the arc to the other, where v represents the velocity.

STATISTICS is that department of political science which is concerned in collecting and arranging facts illustrative of the condition and resources of a state. To reason upon such facts and to draw conclusions from them is not within the province of statistics; but is the business of the statesman and of the political economist. In order to exemplify the precise character and limits of statistics, the Statistical Society of London have aptly chosen for their emblem a wheat-sheaf, with the motto "aliis exterendum."

That it is necessary for a government, in order to govern well, to acquire information upon matters affecting the condition and interests of the people, is obvious. Indeed the civilisation of a country may almost be measured by the completeness of its statistics; for where valuable statistical records of ancient date are found concerning a country not yet advanced in civilisation, which would appear to contradict this position, we owe them to sovereigns or governments of uncommon vigour and sagacity. However rude the government of a country may be, it cannot attempt to make laws without having acquired the means of forming a judgment, however imperfect, as to the matters brought under its consideration. In this sense statistics may be said to be coeval with legislation; but as the latter has rarely been conducted upon any fixed principles, or partaken of the character of science, in the earlier ages of the world, we must attribute to statistics, as a department of political science, a much later origin. It is chiefly to the rise of political economy that we are indebted for the cultivation of statistics. The principles of that science, which are directly concerned about the prosperity and happiness of mankind, were not reduced to any system until the middle of the last century; since that time, political economy has been cultivated as an inductive science. The correctness of preconceived theories has been tested by the observation and analysis of facts; and new principles have been discovered and established by the same means. A limited knowledge of facts had previously been an obstacle to the progress of political economy; and on the other hand the neglect of that science caused indifference to statistical inquiries.

This connection between political theories and statistics, while it has led to the collection of many data which would not otherwise have been obtained, has too often introduced a partial and deceptive statement of facts, in order to support preconceived opinions. This is sometimes unjustly objected to statistics, as if it were a defect peculiar to them. That facilities for deception are afforded by statistics cannot be denied; but fallacies of this kind, like all others, are open to scrutiny and exposure. Reliance need not be placed upon statements of facts nor on numbers, unless supported by evidence; and inferences from them should only be admitted according to the rules by which all sound reasoning is governed. Fallacies are difficult to detect in proportion to the ingenuity of the sophist and the ignorance or inexpertness of his opponents; but in political matters, opposite theories and opinions are maintained with equal ability, and facts and arguments are investigated with so much jealousy, that, in the end, truth can hardly fail to be established. Neither does any suspicion of partiality attach to such facts as are collected by a government without reference to particular theories. Until some one has shown the value of noting a certain class of facts with a view to his own inquiries, no pains are taken to obtain information of that nature from the best sources; but as soon as the importance of seeking any data is acknowledged, the collection of them becomes the business of impartial persons. The statist must be acquainted with the purposes to which the facts collected and arranged by him are likely to be applied, in order that the proper distinctions and details may be noted in such a manner as to give the fullest means of analysis and inference; but his services are greatest when he does not labour in support of a theory.

It thus becomes the duty of a government to apply all the means in its power in aid of statistics, not only for the administration of the affairs of state, but also for the furtherance of political science, and for general information. Abundance and accuracy must be the object of a government in collecting statistical facts.

We would lay much stress upon the collection of facts by the highest authority of the state, because the classes of facts most important in political inquiries can scarcely ever be searched out by other persons, who have not access to the offices of government, and who are without authority to demand information; while the government has ample means at its disposal, and can, without difficulty, and in the ordinary course of executive business, obtain statistical information of the highest value. In this and many other countries the respective governments are applying themselves earnestly to statistical investigations. In England a statistical department has been established at the Board of Trade to collect and arrange all the documents of a statistical nature that can be obtained through any department or agency of government. The admirably organised departments of the French government have abundance of statistical materials systematically collected, which they never fail to arrange in a very lucid manner, and to analyse with much ability. Great credit is due to the Belgian government for the diligence with which its several departments have engaged in statistics under the superintendence of a central statistical commission. Austria, Prussia, and other European governments, have also more or less complete and comprehensive statistical departments.

But while governments are thus engaged, there is ample room for the labours of individuals. Local statistics of all kinds are open to them. The books and records of public institutions, facts relating to particular trades, to the moral and social state of different classes of society, and other matters apparently of local interest only, often present results as important as those derived from inquiries on a more extended scale. Good service also may often be done by a judicious selection and comparison of matters not brought together in official statements, with a view to the illustration of principles of science or experiments in legislation, and by suggestions and criticism, which may direct the attention of government to particular branches of inquiry, to improvements in the mode of carrying them on, or in the form in which they are published.

It would be useless to attempt an enumeration of the various matters that are included in the province of statistics, but for the more convenient consideration of the subject we may indicate its division into—1, Historical statistics, or facts illustrative of the former condition of a state; 2, Statistics of population; 3, of revenue; 4, of trade, commerce, and navigation; 5, of the moral, social, and physical condition of the people.

The article CENSUS will serve as an example of the use to which such materials may be applied, and the parliamentary returns of the Board of Trade and the criminal and legal statistics now published annually furnish other examples.

STATUARY, STATUE. [SCULPTURE.]

STATUTE. Bills which have passed through the houses of Lords and Commons and received the royal assent become acts of parliament, and are sometimes spoken of collectively as forming the body of "statutes of the realm." In a more restricted application of the word, private acts are excluded, and even public acts, when their purpose is temporary. The meaning of the word is even more restricted when the measures of the early parliaments are in question, for many acts received the royal assent, and are found on the Rolls of Parliament, which are not accounted statutes.

The Statutes of the realm, properly so called, were at a very remote period written in books apart from the other constitutions and charters of the monarchy, and received by the courts as of equal authority with the ancient customs of the realm.

Three volumes, in the custody of the Master of the Rolls, contain the body of those enactments which are called "statutes." One contains those passed before the beginning of the reign of Edward III.; and the other two, those from 1 Edward III. to 7 Henry VIII., all very fairly written. These books are not considered in the light of authorised enrolments of the statutes. For the authentic and authoritative copies, if any question arise, recourse must be had (1) to what are called the Statute Rolls, which are six rolls containing the statutes from 6 Edward I. to 8 Edward IV., except from 8 to 25 Henry VI.; (2) to the enrolments of acts of parliaments which are preserved in the Rolls chapel from 1 Richard III.; (3) to exemplifications and transcripts with writs annexed, signifying that they were transmitted by authority to certain courts or other parties, who were required to take notice of them; (4) in those since 12 Henry VII., to the original acts in the parliament office; (5) the rolls and journals of parliament; (6) the close, patent, fine, and charter rolls; on which statutes are sometimes found.

With the parliament of the reign of Richard III. began the practice of printing, and in that manner publishing, the acts passed in each session. This followed very soon on the introduction of printing into England. Before that time it had been a frequent practice to transmit copies of the acts as passed to the sheriffs of the different shrievalties to be by them promulgated. The practice of printing the statutes has continued to the present time.

Before the first of Richard III., the aid of the press had been called in to give extended circulation to the older statutes. Before 1481 it is believed that an abridgment of the statutes was printed by Letton and Machlinia, which contains none later than 33 Henry VI., 1455. To the next year is assigned a collection, not abridged, from 1 Edward III. to 22 Edward IV. Next to these in point of antiquity is to be placed a collection printed by Pynson about 1497, who also, in 1508, printed what he entitled 'Antiqua Statuta,' containing Magna Charta, Charta de Foresta, the Statutes of Merton, Marlbridge, and Westminster primum and secundum. This was the first publication of those very early statutes.

In the reign of Henry VIII. the first English abridgment of the statutes was printed by Rastall; and during that reign and in the succeeding half century there were numerous impressions published of the old and recent statutes in the original Latin and French, or in English translations. Barker, about 1587, first used the title 'Statutes at Large.'

In 1618 two large collections of statutes ending in 7 James I., were published, called Rastall's and Pulton's. Pulton's collection was several times reprinted with additions.

In the 18th century an addition, in six folio volumes, was published by Mr. Serjeant Hawkins in 1735, containing the statutes to 7 George II. Cay's edition, in 1758, in the same number of volumes, contains the statutes to 30 George II. Continuations of these works were published as fresh statutes were passed; and another work in 4to, of the same kind, was begun in 1762, well known by the designation of Ruffhead's 'Statutes at Large.' Pickering's edition is in 8vo., and ends with 1 George III.

None of these collections, however, had ever been published by authority of the state. This led a committee of the House of Commons, who, in 1800, were appointed to inquire into the state of the Public Records, to recommend, among other things, that "a complete and authoritative edition of all the statutes should be published." And finally, between the years 1810 and 1824, the Record Commissioners appointed, in pursuance of this recommendation, produced a critical edition of the statutes (including the early public charters), ending with the close of the reign of Queen Anne. This is the *authentic* edition of the statutes. It is supplied with a valuable index, and forms ten folio volumes. In the introduction to that work there is a more particular account of the former editions of the statutes and of the means for making such a work as this complete.

The statutes passed in the Imperial Parliament of Great Britain are now printed by the queen's printers, and sold at fixed prices.

These "Statutes of the Realm" are generally divided into two classes—Public and Private; but they may more conveniently be distributed into three classes—Public General, Public Local, and Private. The two former only come within the term "laws," in the proper acceptation of the term. The private acts embody special privileges conferred on individuals, or the sanction of the legislature to private arrangements regarding property; and before they can be enforced, they must be pleaded before the courts of law, like contracts, or the titles of estates. The public local statutes, though published separately, and though the standing orders of the Houses of Parliament require that, on account of the private interests which they are often likely to affect, certain preliminary notices and other proceedings should take place before they are passed through their stages, are yet, in contemplation of law, in the same position as the public general statutes.

Formerly all the public statutes, local and general, were published together and numbered consecutively; but from the year 1798 downwards, the local acts have been separately enumerated. From the number of railway and other joint-stock schemes, this branch of legislation increased so rapidly a few years ago, that it became necessary to simplify and abbreviate it. Steps were taken to accomplish this end by passing what are known as Consolidation Acts, such as the Land Clauses Consolidation Act, the Railway Clauses Consolidation Act, &c., &c., a distinct series being passed applicable to Scotland; but there is yet room for further legislation in the same direction.

STATUTE (SCOTLAND). It would be difficult to explain the character of the older legislation of Scotland, the method in which it was sanctioned, or the constitution of the bodies by which it was passed. All the light that probably is to be obtained on the early history of the statute-law has lately been embodied by Mr. Innes, in his preface to the edition of the 'Scottish Statutes and Old Laws,' published by the Record Commission. "Whatever," he says, "may be the case in other countries, it is not easy in Scotland to distinguish the ancient legislative court or council of the sovereign from that which discharged the duty of counselling the king in judicial proceedings. The early lawgivers, indeed, enacted statutes by the advice of the 'bishops, earls, thanes, and whole community,' or 'through the common counsel of the Kynryk;' but during the reigns previous to Alexander III. we find the king also deciding causes in a similar assembly of magnates; while laws of the greatest importance, and affecting the interest of whole classes of the community, bear to be enacted by the king and 'his judges.'" It is probable that the practice of the assembly, legislative or judicial, of the principal barons, though irregular, was in general an imitation of the parliament of England.

Before the war of independence, the lands of the southern districts of Scotland had been in a great measure partitioned among Norman adventurers, some of whom owed a double allegiance to the crowns both of England and Scotland; and it was natural that they should bring with them the practices and opinions of the country with which they were earliest connected. A large proportion of the lowland population of Scotland were at the same time Saxon refugees from England. So early as the reign of David I. (1125) we begin to find that the municipal corporations had a voice in the ratification of the laws. "The parliament," says Mr. Innes, "assembled by John Balliol at Scone, on the 9th of February, 1292, was probably the first of the national councils of Scotland which bore that name in the country at the time, although later historians have bestowed it freely on all assemblies of a legislative character. We have no reason to believe that any change in its constitution occasioned the adoption of the new term, which soon became in Scotland, as in England, the received designation of the great legislative council solemnly assembled. It was not till a few years later, on occasion of negotiating an alliance with France, that Balliol, probably at the desire of the French king, procured the treaty to be ratified, not only by the prelates, earls, and barons, but by certain of the burghs of his kingdom. That treaty was finally ratified at Dunfermline on the 23rd day of February, 1295; and the seals of six burghs were then affixed to the deed, along with those of four bishops, four monasteries, four earls, and eleven barons. Notwithstanding this very formal ratification, however, it may be doubted, both from the peculiar phraseology of the deed itself, and from the silence of historians as to any meeting of a parliamentary nature in which it could have been voted, whether the parties stated as consenting, and especially whether representatives of those six burghs, were actually present as in a national assembly or parliament."

The acts which were thus sanctioned—sometimes, perhaps, by the separate adhesion of the principal interests of the country, sometimes in assemblies—were of a mixed character. Some were judgments in particular disputes, accompanied probably by the announcement of a principle on which such questions should thenceforth be decided; others were acts of executive authority; and others might be regulations having the character of fixed and general laws. When these proceedings related to matters of private right, the recording instrument would be put into the hands of the party interested. "When the proceedings of the national council," says the authority already cited, "related to matters of a more public nature, such as negotiations with foreign states, its earliest records were probably of a similar kind, and consisted of nothing more than the indentures or other diplomacy which embodied the results of its deliberations. Perhaps the earliest instances of this kind that now remain are those important deeds of the reign of Alexander III., when, however, a more artifical system must have been beginning to prevail. It would be still more interesting to ascertain the modes in which the more general ordinances and laws of the realm were enacted and recorded; but on this head the loss of every original document has left us entirely to conjecture. Judging, however, from the mutilated and imperfect transcripts of a later age, and from the analogy of the other states of Europe, it would appear that the more important and general statutes were framed into short capitulars, and ingrossed into a writ, addressed, in the name of the king, to the chief ministers of the law in the different districts of the kingdom, requiring the publication and observance of them. The laws of the burghs, the assizes of David I. and of William, and the statutes of Alexander II., as found in the old manuscript compilations of lawyers, seem to be the fragments of various capitulars of this kind." The assizes of David I., 'Assisé Regis David,' are reported to be the oldest fragments of legislation in Scotland, and are partly, but not entirely, traceable to so early a period as the reign of the king with whose name they are associated. The burgal laws, 'Leges Quatuor Burgorum,' constitute the oldest systematic collection of laws. They too may be referred to the reign of David; and though historians give him the credit of having planned the whole system of the municipal corporations, it is more likely that this code of laws embodies the privileges and restrictions which had gradually come into existence with the growing influence of the burghs. The coincidence between these early vestiges of Scottish legislation and the old law of England is remarkable. Both in the assize and in the burgh laws technical phraseology is frequently used, which still belongs to the law and practice of England, but has long been disused in Scotland. Indeed, it is very clear that before the attempt of Edward I. there was much harmony in tone and spirit between the two nations, and that Scotland generally followed or accompanied England in her constitutional progress. There is a still more remarkable coincidence of legislation in the celebrated 'Regiam Majestatem,' or general code of the old laws of Scotland. It was, like the fragments mentioned above, attributed to David I., who had obtained the character of the Justinian of Scotland; but it is undoubtedly of later date. In the 16th and 17th centuries it was very popular, as an undoubted early national code; but it was subsequently discovered to have many features in common with the compilation 'De Legibus et Consuetudinibus Angliæ,' attributed to Ranulph de Glanvil, justiciar of England; and then it acquired the evil reputation of being a code prepared by Edward I., for the purpose of subjecting Scotland to the law of England.

The 'Regiam Majestatem,' so named from the words with which it commences, is, along with the burgh laws, and other vestiges of early legislation, printed in the first volume of the edition of the Scottish statutes issued by the Record Commission. None of the contents of this first volume, however, come within the description of the accepted statute law of Scotland. In 1566 a commission was issued for the collection and publication of the statute law, and they speedily published a series of statutes reaching from 1424 to 1564. It is at the former date that the statute law, properly speaking, commences, and it proceeds thence in a regular series to the Union with England. The Scottish acts are referred to by the date of the parliament in which they are passed, and their numerical order; as, "The Act 1424, c. 25;" "The Act 1661, c. 16." These early statutes are brief and sententious, and were admired by Bacon for "their excellent brevity."

From the date of the accession of Bruce, after the war with England, the Scots long entertained a feeling of national jealousy and enmity towards England; and though some of the kings introduced southern practices, we do not find that steady imitation and adoption of the constitutional movements of the English parliament which characterise the earlier period, but rather an isolated creation of, and adherence to, national peculiarities. The subsequent creation of the Court of Session, in imitation of foreign tribunals, to administer justice, according to the rules of the Civil Law, has eradicated nearly all the traces of similarity in laws and procedure which formerly existed between the judicial systems of Scotland and England.

Of the Statutes of the Scottish parliament, those only are now law which are said to be *in viridi observantiâ*. By this principle the statute law has silently adapted itself to the character of the times; and, though not formally repealed, the barbarous laws of periods of bigotry or violence have ceased to be enforceable. Since the Union of 1707, it has been considered, in conformity with the English doctrine, that an act passed by the British parliament must be held as law, and judicially enforceable, until it is repealed.

The law of Scotland, the judicial and executive system, and the ecclesiastical polity, being quite distinct from the corresponding institutions of England, many statutes are from time to time passed by the British legislature solely applicable to Scotland, prepared by persons professionally acquainted with the institutions of that part of the empire. The revenue laws of Scotland were formerly distinct; but now, with few exceptions, one system embodied in one series of acts applies to the United Kingdom. In matters of national policy, and frequently in the criminal law and in legislation for internal economy, acts are made applicable both to England and Scotland at the same time.

STATUTE (IRELAND). In Ireland, the method by which the early irregular convocations, called parliaments, passed their acts, appears to have been a close imitation of the English practice. The authenticated printed statutes begin in the year 1310, 3 Edw. II. After five short acts of this parliament there is a hiatus until the year 1429, although it is known in history that repeated parliaments were held in the interval. Many of these statutes are characteristic indications of the state of the country, and throw light on the domination of the English over the natives—for example, the 25 Hen. VI. c. 4, "An Act, that he that will be taken for an Englishman, shall not use a Beard upon his upper Lip alone; the Offender shall be taken as an Irish Enemy:" 28 Hen. VI. c. 3, "An Act, that it shall be lawful for every Liegeman to kill or take notorious Thieves, and Thieves found robbing, spoiling, or breaking Houses, or taken with the manner:" and in later times (the 7 Will. III. c. 21), "An Act for the better suppressing Tories, Robbers, and Rapparees; and for preventing Robberies, Burglaries, and other heinous Crimes." The Statute of Drogheda, commonly called Poyning's Law, passed in 1495 (10 Hen. VII.), had a marked influence on the later legislation and constitutional history of Ireland; as by it, all the acts then or late passed in England, "concerning or belonging to the common and public weal of the same," should be law in Ireland. It further provided that no measure should be proposed for the adoption of parliament until it had first received the royal assent in England. It is believed that this badge of servitude prevented the passing of many exterminating acts, which, in times of anarchy, discord, or tyranny, the Irish ministry, and their partisan-parliaments, would have readily passed. This act was repealed, and the independence of the Irish legislature restored by the measure of 1783. At the Union, in 1800, the Irish Parliament was merged in that of Great Britain and Ireland.

STATUTE OF FRAUDS. This name is applicable to any statute the object of which is to prevent fraud, but it is particularly applicable to the 29 Car. II. c. 3, which is entitled the "Statute of Frauds and Perjuries." One object of the statute was to prevent disputes and frauds by requiring in many cases written evidence of an agreement. Before the passing of this statute many conveyances of land were made without any writing as evidence of the conveyance. An estate in fee-simple could be conveyed by livery of seisin, accompanied with proper words, and a use could also be declared by parol. No writing was necessary to convey any estate in possession, for such estate is technically said to lie in livery; but a reversion could only be conveyed by deed. The Statute of Frauds declared that all leases, estates, and interests of freehold or terms of years or any uncertain interest in any lands or hereditaments, made by livery and seisin only, or by parol, and not put in writing and signed by the parties, &c., shall have the force of leases or estates at will only. But leases for not more than three years, whereon the rent reserved shall be two-thirds of the full improved value of the thing demised, are excepted by the statute. Further, no lease, estates, or interest either of freehold or terms of years, or any uncertain interest, not being copyhold or customary interest, shall be assigned, granted, or surrendered except by deed or note in writing. Another section of the statute provides that all declarations or creations of trust or confidences of any land, tenements, or hereditaments shall be manifested and proved by some writing signed by the party who is by law enabled to declare such trust, or by his last will in writing, or they shall be void. The 5th section of this statute declared that all devises of lands or tenements, as more particularly described in this section, should be in writing and signed in the manner here prescribed by three or four credible witnesses; and the 6th section related to the revocation of a devise in writing of lands or tenements. Both these sections are repealed by the 1 Vict. c. 26, which makes alterations in other provisions also of the Statute of Frauds.

There are several other important provisions in this statute, which may be omitted here. The purpose of the statute is to prevent fraud by requiring the evidence of writing, which is a better kind of evidence than men's memory. Its enactments have been usefully amended by the Mercantile Law Amendment Act, 1856, especially with reference to guarantees.

STATUTE MERCHANT. [Acton Burnel, Statute of.]

STATUTE STAPLE. [Staple.]

STATUTES OF LIMITATION. There appear to have been no times limited by the common law within which actions might be brought; for though it is said by Bracton (lib. 2, fol. 228), that, "omnes actiones in mundo infra certa tempora limitationem habent;" yet with the exception of the period of a year and a day, mentioned by Spelman ('Gloss.', 32), as fixed by the ancient law for the heir of a tenant to claim after the death of his ancestor, and for the tenant to make his claim upon a disseisor, all the limitations of actions in the English law have been established by statute. Certain remarkable periods were first fixed upon, within which the cause of action must have arisen. Thus in the time of Henry III., the limitations in a writ of right, which was then from the time of Henry I., was by the Statute of Merton, c. 8, reduced to the time of Henry II.; and by the Statute of Westminster, 1, c. 8, the period within which writs of right might be sued out was brought down to the time of Richard I. (Co. Lit., 114 b.)

Since the 4 Hen. VII., c. 24, which limited the time within which persons might make their claim to land of which a fine had been levied with proclamations, various statutes have been passed for the purpose of limiting the time within which actions and suits relating to real property may be commenced. The 21 Jac. I., c. 16, enacted generally that no person should make entry into any lands, but within twenty years next after his right of entry accrued.

By the 9 Geo. III. c. 16, the right of the crown to sue or implead for any manors, lands, or other hereditaments (except liberties or franchises) was limited to sixty years. Before this act, the rule that *nullum tempus occurrit regi* was universal. It still prevails as a maxim where not abridged by statute.

The next statute upon this subject is the 3 & 4 Will. IV. c. 27, by which great changes were made in the remedies for trying the rights to real property, and which embodies the greater part of the present law of limitations relating thereto.

No entry or distress can be made or action brought to recover any land or rent, but within twenty years after the right has accrued to the claimant, or some person through whom he claims.

But persons under the disability of infancy, coverture, idiotcy, lunacy, unsoundness of mind, or absence beyond seas, or persons claiming under them, notwithstanding the period of twenty years shall have expired, are to be allowed ten years after the person to whom the right first accrued has ceased to be under any disability or has died. Forty years is, however, a complete bar.

No part of Great Britain and Ireland, nor the adjacent islands, is to be deemed beyond seas, within the meaning of this act.

A mortgagee to whom a payment of principal or interest has been made, or an acknowledgment in writing has been given, has twenty years from the time of such payment or acknowledgment. (7 Will. IV. and 1 Vict. c. 28.)

Arrears of dower, or damages for such arrears, are not recoverable by any action or suit beyond six years before the commencement of the action or suit. Before the act, there was no limitation either at law or in equity to a claim for arrears of dower during the life of the heir. No arrears of rent or of interest in respect of any money charged in any manner on land or rent, or any damages in respect of such arrear of rent or interest, can be recovered but within six years next after the same respectively became due, or next after an acknowledgment in writing given to the person entitled thereto or his agent, signed by the person by whom the same was payable, or his agent.

The rents here dealt with are rents charged upon land only, to which the former statutes did not apply, and not conventional rents, the limitations as to which are provided for by the 21 Jac. c. 16, s. 3, and the 3 & 4 Will. IV. c. 42.

Limitations as to tithes and other ecclesiastical property are now regulated by 2 & 3 Will. IV. c. 100, and 3 & 4 Will. IV. c. 27.

As to advowsons, the 3 & 4 Will. IV. c. 27, s. 30, enacts that no *Quare impedit* or other action is to be brought after the expiration of the period during which three clerks in succession shall have held the same, all of whom obtained possession adversely to the right of the person claiming, or of the person through whom he claims, if the times of such incumbencies together shall amount to sixty years, and if not, then after such further period as with the times of such incumbencies shall make up the period of sixty years.

Limitations as to other incorporeal rights are now mainly regulated by 2 & 3 Will. IV. c. 71. [Prescription.]

The limitation in actions of assault and battery, is, by 21 Jac. I. c. 16, s. 3, four years after the cause of action arises.

Actions of slander must, by the same statute, be commenced within two years next after the words spoken.

The limitation applicable to actions arising upon simple contract, and actions founded in wrong, is, by 21 Jac. I. c. 16, s. 3, six years next after the cause of action arises.

Formerly there was no limitation applicable to a suit for a legacy, though in some cases presumption of payment was admitted. The 3 & 4 Will. IV. c. 27, s. 40, is applicable to all legacies, whether charged on real estate or not.

The limitation on actions arising upon specialty is, by 3 & 4 Will. IV. c. 42, twenty years.

Actions of debt for rent upon an indenture of demise, actions of covenant or debt upon bond or other specialty, and actions of debt or *scire facias* upon recognisance must therefore be commenced and sued within twenty years after the cause of such actions or suits arises. But if any acknowledgment has been made, either by writing signed by the party liable, by part payment, or part satisfaction, on account of any principal or interest then due thereon, the person entitled may bring his action for the money remaining unpaid, and so acknowledged to be due, within twenty years after such acknowledgment or part payment, and in case of the plaintiff being under disability, within twenty years of the removal of such disability.

The limitations of actions on penal statutes is, by 31 Eliz. c. 5, s. 5 (which act repeals a previous one, the 7 Hen. VIII. c. 3, upon the same subject), two years after the commission of the offence, if the suit be by the crown; and one year after the commission of the offence if by a private prosecutor.

A prosecution by the party grieved was not within the statute; but now, by the 3 & 4 Will. IV. c. 42, s. 3, all actions for penalties, damages, or sums of money given to the party grieved by any statute now or hereafter to be in force must be brought within two years after the cause of such actions or suits.

By the 24 Geo. II. c. 44, s. 1, actions against justices of the peace and constables or others acting in obedience to their warrants are limited to six calendar months.

There is no time limited by any statute for indictments for felonies and other misdemeanors when there is no forfeiture to the queen or to the prosecutor.

A charity is never considered in equity as absolutely barred by the statutes, or by any rule of limitation analogous to them; but the court takes notice of a long adverse possession in considering the effect and construction of instruments under which claims are set up on its behalf.

The statutes of limitation must in general be pleaded positively by the defendant in any action at law, who wishes to take advantage of them, and it has been held in equity that unless the defendant claims the benefit of the statutes by plea or answer, he cannot insist upon them in bar of the plaintiff's demand.

STEALING. [Larceny.]

STEAM AND STEAM-ENGINE. *Steam* is the gas or vapour given off by a liquid, when its temperature is raised to such a degree as to cause it to pass into a state of ebullition; but as the vapour of water so given off is the one most commonly applied in the mechanical arts, attention will be called principally to that particular kind of steam in the ensuing notice.

Steam or vapour in its natural state, like all gases, is transparent and colourless; its visibility in air being caused by its partial condensation, which gives rise to the formation of small vesicles of water, enclosing transparent steam, of such a nature as to refract and absorb light. It seems that the phenomenon of the generation of steam is affected by the following general laws, namely: 1st, that the temperature of the ebullition of a liquid is the same at all times, under the same pressure and in a vessel of the same substance: 2nd, that the temperature of the liquid remains constant during the whole period of the ebullition, provided the pressure remain the same, and if a greater quantity of heat be communicated to the vessel containing the liquid at one stage of the process than at another, the only effect will be that a greater quantity of steam will be evolved: the temperature of the liquid will not be raised: 3rd, that the volume of the steam will be much greater than that of the liquid furnishing it, and that the volume of the vapour of water, for instance, will be about 1700 times greater than that of the water itself. The temperatures at which particular substances pass into steam are very different, it may be added; thus whilst water boils at 212°, ether boils at 98·6°; concentrated sulphuric acid, at 617°; mercury, at 680°; sulphur, at 752°, &c. Even the most refractory metals when properly treated can be made to pass into the state of vapour, and there are others which pass into the gaseous state without passing through the liquid form, as for instance camphor, arsenic, iodine, &c., under which circumstances they are said to *sublime ;* whilst liquids occasionally pass into the state of vapour at temperatures below those required for ebullition, and they are then said to *evaporate.* Water evaporates at all temperatures; ice, and snow, sublime in dry winds.

The law with respect to ebullition ascertained by Dalton, namely, "that the elastic force of the vapour given out during the process is equal to the exterior pressure," allows us to calculate the former from the temperature at which ebullition takes place, if we possess tables showing the elastic force of steam at the different temperatures; and it is upon this principle that hypsometric observations with respect to the altitudes of mountains are made, by ascertaining the boiling point of water in open vessels. Very great precautions are requisite in observations of this description, but with the aid of the hypsometric thermometer of M. Regnault, very useful checks upon the other modes of ascertaining altitudes may be obtained. Amongst other essential points to be taken into account in these observations the nature of the vase must not be neglected, for Gay-Lussac observed that water required a greater degree of heat to pass into a state of ebullition when it was boiled in a glass vase than when it was boiled in a metal one: and it is well known that when the vase is covered with a material with which water may have less cohesion than it has with the metal, the boiling point may be lowered. Thus, if the boiling point of water in a metal vase be at any place 212°, it would usually be 213°·96 in a glass vase; but if the glass be covered by a coating of shell lac, the boiling point would become about 211°·64. It also appears that the quantity of air diffused through the water has a considerable effect on the formation of steam; for unless there be air in dissolution, the cohesion of the particles of the water will oppose the disengagement of steam, excepting upon the surface. Galy Cazalat found indeed that, by excluding air from water exposed to heat, it was possible to raise the temperature to about 253°·4 without ebullition, but that at that temperature part of the water flashed into steam with a violent explosion. There are some curious facts connected with the spheroidal condition of water in contact with incandescent materials which are worthy of the attention of the physical philosopher; but as they have not hitherto led to any practical results, the reader is referred, for a view of the present state of our knowledge on this subject, to the works of Boutigny, Pouillet, Poggendorff, Perkins and Faraday.

The temperature of ebullition is not affected by the presence of substances in suspension in the liquid considered; but when those substances are in solution they produce a very distinct effect, and in the proportion that the new ingredient is more or less volatile than the liquid, will the boiling point be lowered or raised. Salts dissolved in water retard its ebullition, and they do so in an increasing ratio until the point of saturation has been reached, beyond which the boiling point remains constant; but it is to be remarked that the precise temperature of ebullition of a saline solution is not to be judged by the degree of heat that solution may temporarily attain; for it is possible to raise the temperature to a certain degree, but directly the salt begins to be precipitated the temperature may fall. Thus, a solution of the carbonate of potash was observed by Legrand to attain 284° without parting with that substance; but suddenly a great effervescence took place, and the temperature fell to 275°, accompanied by a copious deposition; after which the temperature remained constant. M. Legrand gave a table of the boiling points of the different saturated saline solutions, from which the following statement is copied; the temperatures are of course given in this table, and throughout this article, unless otherwise mentioned, on the Fahrenheit scale.

Salts.	Salt in 100 parts of water.	Temperature.	Salts.	Salt in 100 parts of water.	Temperature.
Chloride of sodium .	41·2	227·12°	Sal ammoniac . .	88·9	237·56°
,, potassium	59·4	226·94	Chloride of strontium	117·5	244·18
,, barium .	60·1	219·92	Carbonate of potash .	205·	275·0
Carbonate of soda . .	48·5	217·33	Nitrate of lime . .	362·	271·8
Nitrate of soda . .	224·8	249·8	Acetate of soda . .	209·	261·7
,, ammonia .	No limit	356·	,, potash .	798·2	336·2
Chloride of calcium .	325·0	355·1	Phosphate of soda .	112·6	234·7

The boiling point of water being 212°, that of concentrated nitric acid will be 186°·8; that of alcohol will be 174°·2; that of oil of turpentine will be 314°·6; and that of linseed oil 600°·8. Sea water, containing $\frac{1}{33}$ of its own weight of the chloride of sodium, boils at 213°·2 in the open air; if the proportion of salt be increased, the temperature of ebullition will increase also; thus, for $\frac{2}{33}$ of salt it becomes 214°·4; for $\frac{3}{33}$, it becomes 215·°5; for $\frac{4}{33}$, 216·°7; for $\frac{5}{33}$, 217·°9; for $\frac{6}{33}$, 219°; for $\frac{8}{33}$, 221°·4; for $\frac{10}{33}$, 223°·7; for $\frac{12}{33}$, or the point of saturation, 226°. It may be interesting to the practical reader here to state, that marine boilers are usually worked with proportions of salt equal to $\frac{2}{33}$ of the weight of the water; but that occasionally those proportions are raised as high as $\frac{4}{33}$ without much inconvenience.

For mechanical purposes, it is necessary that steam should exercise a pressure in excess of that of the atmosphere; and, upon Dalton's law above quoted, this additional pressure, or elastic force, can only be obtained by causing the water to boil under such conditions as shall bring to bear upon its surface an effort equivalent to the one the steam is desired to exercise. It is a matter of the greatest importance in the arts, then, to ascertain the temperature of the water which corresponds with steam of certain pressures, and numerous experiments have been made for this purpose. Messrs. Dulong and Arago, M. Regnault, and Macquorn Rankine, may be cited as the greatest authorities on the subject; and the reader who may desire to study this branch of physical science in detail is referred to their works, as also to those of Wollaston, Lavoisier, Laplace, Gay-Lussac, Petit, De Pambour, Lubbock, Mosely, &c. The tables drawn up by Messrs. Arago and Dulong of the elastic force of steam at the different temperatures observed during their experiments, or ascertained by calculation by means of a formula deduced from those experiments when the elastic force of the steam exceeded 392·8 lbs. on the superficial inch, are sufficiently accurate for practical purposes, though M. Regnault's later researches are more elaborately correct. Arago and Dulong's table is to be found in Daguin's 'Traité de Physique,' and elsewhere; the pressure being indicated in atmospheres of 14·7 lbs. on the superficial inch, and the temperatures are given on the centigrade scale. Macquorn Rankine, however, gives in his 'Treatise on the Steam Engine,' p. 564, a table, from which the following statement of the tension and the boiling points is extracted; the tension being given in pounds, the temperature of the water, producing the steam of that elastic force, in degrees of Fahrenheit's scale.

Table of temperature of water able to produce steam possessing the elastic force indicated, in lbs. avoirdupois per superficial inch :—

Temperature.	Force.	Volume of 1 lb. of steam in cubic feet.	Temperature.	Force.	Volume of 1 lb. of steam in cubic feet.
212°	14·70	26·36	329°	101·9	4·280
221	17·53	22·34	338	115·1	3·814
230	20·80	19·03	347	129·8	3·410
239	24·54	16·28	356	145·8	3·057
248	28·83	14·00	365	163·3	2·748
257	33·71	12·09	374	182·4	2·476
266	39·25	10·48	383	203·3	2·236
275	45·49	9·124	392	225·9	2·025
284	52·52	7·973	401	250·3	1·838
293	60·40	6·992	410	276·9	1·672
302	69·21	6·153	419	305·5	1·525
311	79·03	5·433	428	336·3	1·393
320	89·86	4·816			

In practice, the pressure of steam is reckoned without any reference to that of the atmosphere; or, in other words, it is only the pressure in excess of the atmospheric pressure which is noticed. Ordinary condensing engines, said to be working at from 16 to 40 lbs. pressure, would, according to the above table, work with steam of an elastic force of from 30·7 to 54·7 lbs.; high pressure engines, working at from 60 to 120 lbs. pressure, really work with steam of 74·7 and 134·7 lbs. of the table, and the temperature of the water would in both cases correspond with the higher degrees of elastic force. The laws connected with the relations between the temperature and pressure above stated are, moreover, sometimes applied practically in the arts as a precaution against danger from an accidental increase of pressure; for, on the continent, it is usual to place in a steam-boiler, intended to work under high pressure, plugs of mixed metals able to fuse at temperatures which would generate steam of a dangerous nature. When these plugs fuse, the water escapes, and consequently puts out the fire; they do not, however, dispense with safety-valves.

A great number of formulæ have been proposed for the purpose of calculating the relation between the elastic force of vapour and the temperature of the water producing it; such are the formulæ of Laplace, Ivory, Poisson, Lubbock, De Prony. The simplest of them is unquestionably the one given by Dr. Young, $F=(1+0{\cdot}0029t)^7$; or, as given by Arago and Dulong for the centigrade scale, $F=(1+07153t)^5$; and Regnault found that the results it gave corresponded very nearly with those obtained by actual observation, when the vapour was given off from water heated beyond 212°, but that below that temperature the results no longer agreed. Regnault adopted, therefore, another formula proposed by Biot, and discussed at length by that philosopher in his 'Traité de Physique,' 1816: but, as this formula contains no less than five constants, and the indications given by the simpler formula of Arago are admitted to be correct for all the pressures dealt with in practice, there can be little reason for adopting the former.

It is important, in calculations with respect to the use of steam as a motive power, to ascertain whether the latent heat of the steam remains the same at all temperatures; and M. Regnault has added to the other services he has rendered to science by going through a series of direct experiments for the purpose of verifying the laws of

Watt and of Southern upon this subject which had previously been received. Regnault found that at the ordinary atmospheric pressure it required 540 thermal units of the French scale to convert 1 gramme of water into steam (971,636 English thermal units to convert 1 pound avoirdupois); and thus far his experiments (recorded in the 'Mémoires de l'Académie des Sciences,' vol. xxi.) agreed with those of other observers. Watt, however, had laid down the law "that the quantity of heat necessary to vaporise a given weight of water was the same at every degree of the thermometer;" and Southern had stated "that the latent heat of vaporisation was the same under every degree of pressure;" De Pambour's observations appeared also to show that, up to a pressure of about 65 lbs. on the superficial inch, Watt's law was substantially correct. Regnault, on the contrary, found that Watt's law was not exact, and that Southern's was still more fallacious; for he found that when the temperature increased, the total heat also increased, but the latent heat diminished. The results of his experiments were given in the following formula, $\lambda = 606{\cdot}5 + 0{\cdot}305t$; in which λ is the total heat (on the centigrade scale), and t the temperature of the steam; the coefficient 606·5 being the value assigned by him as the latent heat of vapour at 0°, and 0·305 the specific heat of steam. Regnault ascertained at the same time that between the limits of 0° and 392° there was hardly any difference in the specific heat of water, so that there was no occasion to take that difference into account. In the Mémoire wherein these observations are recorded a table is inserted, showing the tensions, and the total heat of the vapour given off at temperatures increasing by equal increments of 10 degrees centigrade, between 0° and 230°. The table in question is also given in Daguin's 'Traité de Physique,' t. i., part 2, p. 965. It may be as well to add that the laws of the latent heat of steam are practically applied when buildings are heated by means of it; in these cases the heat absorbed, or rendered latent in one place, is distributed by the pipes which enable the steam to circulate over other parts of a building.

The following table of the densities of vapours is extracted from Daguin's work; it is based upon the experiments of MM. Gay-Lussac and Dumas, and the density of air is taken as unity.

Substances.	Density of vapours.	Point of ebullition.	Substances.	Density of vapours.	Point of ebullition.
		Centigrade.			Centigrade.
Water . . .	0·6235	100°	Sulphuric ether .	2·5860	36°
Hydrocyanic acid .	0·9476	26·5	Sulphide of carbon .	2·6447	47
Alcohol . . .	1·6138	11	Essence of turpentine	5·0130	157
Hydrochloric ether .	2·219	36	Hydroiodic ether .	5·4749	65

Compared with water at its greatest degree of condensation, the density of steam at 212° Fahr. is exactly 1695 less than that of the water, or nearly 1700, as was before stated; or in fact, one volume of water yields nearly 1700 volumes of steam. This is worthy of remark; for the volumes of the oxygen and hydrogen, contained in a given volume of water, occupy under atmospheric pressure a space equal to 2500 times the volume of the latter. It has been suggested that the condensation which thus appears to have taken place during the combination of the permanent gases referred to, may be explained by some change in their electrical state; and it is well known that the evolution of steam, under high pressures, does give rise to electrical phenomena of a very remarkable but hitherto only partially studied description. Messrs. Armstrong, Faraday, Schafthoentl, and Becquerel have, indeed observed that when steam, charged with water in suspension, escapes in such a manner as to exercise friction against a substance opposed to its passage, a development of electricity takes place, and that generally the water or the vapour is positive, and the opposing substances negative. The form, the nature, and the temperature of the orifices affect the development of the electricity to a great extent, and especially does heat retard it; at the same time the amount of electrical action depends on the purity of the water, for a small quantity of salt or acid destroys the property, and a very small proportion of the essence of turpentine causes the nature of the electricity to change; the steam in this case becomes negative. Becquerel evidently attributes the development of the electricity, by the passage of steam under the circumstances recorded in the experiments of Mr. Armstrong, to the friction of the globules of water contained in the steam; but this interesting question has not yet been examined with sufficient accuracy to allow the formation of any absolute opinions on the subject.

Steam-Engine. In conformity with the plan of this Cyclopædia a general outline of the principles of the engine will be here given, the reader being referred to different articles connected with the subject, or to works written specifically on the steam-engine, for more detailed information.

The claim to the invention of the steam-engine has been made a subject of national contention; but the conclusion, arrived at from the discussions which this contention has originated, seems to be, that, in common with all other important applications of physical principles, no individual can lay claim to the invention. Whatever may have been the nature and date of its origin, it has been reared to its present gigantic stature by the fostering care of different countries, and, without detracting from or underrating the efforts of others, England may be justly proud of her share of the glory, a share readily conceded by our competitors.

Considering therefore dispute as unprofitable, and the discussion of dates of patents and improvements as uninteresting, we shall incorporate all that is requisite of the history of the engine with our account of it.

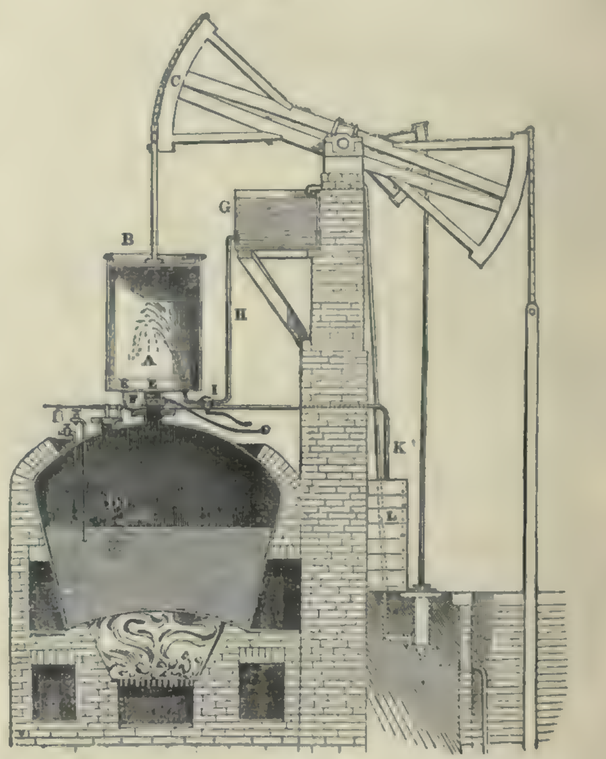
A steam-engine may be defined generally as an engine by which the forces arising from the properties of elasticity and of instantaneous condensation possessed by steam are transmitted to produce a continuous rotatory motion, either of a fly-wheel designed to constitute a reservoir of power for the purposes of driving machinery, or for any other uses that force may be put to.

Admitting this definition, the earlier steam-engines, as they are commonly called, those of the Marquess of Worcester (1663), and the improved forms contrived or suggested by others, and even Captain Savery's (1698), which was long employed in this country, were only *pumps* for raising water: a partial vacuum was formed in close vessels by the condensation of steam within them, the atmospheric pressure raised the water to a certain height; from whence it was forced higher by the elasticity of the steam admitted to act on its surface.

Passing over all these therefore as foreign to our subject, the first engine which it is necessary to describe is that of Newcomen (1705); it constitutes the connecting link between the steam-pumps alluded to, and the modern engine, of which it contained the germ, and into which it was converted by the genius of Watt. [WATT, JAMES, in BIOG. DIV.]

In the subjoined diagram, A represents a *cylinder* open at the uppe end, fitted with a *piston* B, and rendered air-tight by having water on it to the depth of several inches: the *piston-rod* was suspended by a chain from the arched end of a *beam* C, turning on an axle, and having a pump-rod at its other extremity, loaded so as to counterpoise the weight of the piston, and to raise it to the top of the cylinder. This cylinder was placed over the *boiler* D with which it communicated by a steam-pipe E, furnished with a cock F to open or close the passage: G is a cistern fixed above the cylinder, to the bottom of which a pipe H passed, also provided with a cock I.

Fig. 1.



When the piston was depressed to the bottom of the cylinder, it drove out all the air before it, which escaped at the orifice of a pipe K into the water of a smaller cistern L: the cock F being next opened, the steam from the boiler filled the cylinder as the piston rose again from the action of the counterpoise; as soon as it arrived at the top, the cock F was closed and I opened, a jet of cold water from the cistern G rushed into the cylinder, condensing the steam, and thus forming a partial vacuum beneath the piston, the pressure of the air on its upper surface forced it downwards, and caused the pump at the other end of the beam to raise an equivalent weight of water to a height equal to that through which the piston moved: the injected water and condensed steam-water flowed off into the cistern L through K, as the air had previously done. The cock I was now closed, and F opened, and the action was repeated, and when this engine was first introduced, it was the duty of an attendant to open and shut these cocks alternately; but subsequently lever handles to open and shut the cocks were acted on by pins or cams, carried by a rod suspended from a beam; and the engine became self-acting. This improvement was rudely made in the first instance by a boy named Potter, for the purpose of saving himself trouble; it was subsequently perfected by an engineer named Beighton in 1718.

Newcomen's engine was successively improved upon by Smeaton, Brindley, and other engineers, previous to Watt's time, and from its intrinsic merits it remained in general use under the appropriate name of the "atmospheric engine" during the greater part of the last century, but was only used for pumping water.

The first and most important of Watt's improvements on the engine consisted in effecting the condensation in a separate vessel, termed the *condenser*, which communicated with the cylinder. This condenser being filled with steam from the boiler at the same time with the cylinder, the jet of cold water, admitted into the former only, effected the condensation of the whole volume of steam, both of that in the cylinder as well as of that in the condenser, in conformity with the well-known principle in physics, that an action originated in any part of a homogeneous fluid is almost instantaneously communicated throughout its mass.

To effect still further the object of this separate condensation, Watt placed his condenser in a cistern, the temperature of which was kept constant by a fresh supply of cold water, brought from a well by a pump, to be presently mentioned; for otherwise, the heat given out by the condensing steam would, by heating the vessel and the water surrounding it, have prevented the rapid or almost instantaneous condensation necessary to the efficient action of the engine.

To comprehend the necessity for a rapid condensation, it must be remembered that the effective power of the engine depends on the pressure on the piston minus any resistance it encounters and on the space through which it moves. If the steam could be *instantly* converted into water, and so entirely removed,* a perfect vacuum would be formed beneath the piston, in which case, there being no resistance from this source to overcome, a maximum of power would be obtained; but if the condensation be slow, or only partial, since the piston will begin to move the instant there is any inequality in the pressures exerted on its opposite surfaces, its motion will be retarded, or the power diminished, by the resistance to compression offered by the uncondensed steam; and although that resistance would tend to diminish as the condensation proceeded, yet the space occupied by the steam diminishing in consequence of the descent of the piston in nearly the same proportion, the resistance would be nearly constant through the whole of that descent.

On the other hand, to maintain the temperature of the cylinder as high as possible, Watt, at first, cased it in wood to retard the radiation, and subsequently surrounded it by a second iron cylinder, admitting steam from the boiler between the two. This casing, or "jacket," as it is termed, is not used in most modern engines made since Watt's time, for reasons which will hereafter appear; and the effects of radiation from the surface of the cylinder are now chiefly guarded against as much as possible by keeping that surface bright and smooth.

The second of Watt's improvements on Newcomen's engine consisted in closing the cylinder at top, the piston-rod being made to pass through a cylindrical neck in that top, termed a *stuffing-box*, from the passage being rendered steam-tight by a stuffing of tow saturated with grease, which by its lubrication diminished the additional friction resulting from this arrangement. The object of this alteration was to admit of the elastic force of the steam being employed to impel the piston downwards, instead of simple atmospheric pressure. For this purpose, the steam was admitted from the boiler above the piston at the same moment the condensation took place in the condenser; the steam-passage being made double for the purpose, so that the communication with the condenser could be cut off when that with the cylinder was opened, alternately. When the piston had descended to the bottom of the cylinder, the counterpoise at the pump-rod raised it again, as in Newcomen's engine; but to allow of this upward motion, it was necessary to remove the steam which was above the piston, and this was done by allowing it to pass under the piston, and into the condenser through a passage opened at the proper instant for this purpose. Such is the general principle of Mr. Watt's *single-acting* engine, which hence became a *steam-engine*, and was no longer an *atmospheric* one.

By a further improvement, the counterpoise at the pump-rod was done away with, which obviously had been so much added to the unproductive work of the engine, since this weight had to be raised in addition to that of the water. The upward stroke of the piston was now produced by admitting the steam *below* it, to act by its elasticity, as it had previously done *above* when causing the piston to descend: thus the engine became *double-acting*, and assumed that essential general principle which it has ever since maintained, although all the details of its construction have been improved upon by successive engineers.

The changes in the engine introduced by Watt created the necessity for two pumps, and commonly three, which are worked by rods attached to the beam: the first of these is the *hot-water* or *air pump*, intended to remove the air, condensed water, and steam from the condenser, in which they would otherwise accumulate, and finally stop the action; for this water cannot flow away into an open cistern, as it had done in Newcomen's engine, since by Watt's principle it is essential that the condenser should be as steam-tight and as perfectly closed as the cylinder, or else the steam could not exert a pressure greater than that of the atmosphere, as it is intended to do in order to increase the effective force of the engine. The second is a force-pump, required to return the water drawn from the condenser by the first back to the boiler, as will be hereafter explained; and the third, termed the *cold-water pump*, is that alluded to in a preceding paragraph as supplying the cold-water cistern which contains the condenser.

Having thus explained the general principle of the engine, some of the details of its construction must now be considered, and the piston [HYDRAULICS] may claim our first notice, both from its paramount importance and the practical difficulties to be overcome in its formation. In hydraulic machines, all vessels, pipes, valves, &c., must be made *water-tight*: in Bramah's pump, for example, the efficiency of the engine entirely depends on the accurate fitting of parts moving in contact, which must be perfectly water-tight, though subjected to a pressure of many hundred pounds on each square inch of surface;—the utmost perfection of skill in workmanship is requisite to ensure this object, and the difficulty is obviously considerably increased when steam or gases are the fluids to be dealt with. Now the piston of a steam-engine must be *steam-tight*, and yet move with a minimum of friction in the cylinder; and as this latter, from defective workmanship, can never be a perfectly true one, the cylindrical periphery of the piston must be so contrived as to be capable of adapting itself to every inequality in the surface against which it slides: this is effected in common pistons by their being made two inches or more less in diameter than the cylinder, leaving a projecting flange at the bottom, which, together with a top plate bolted to them, accurately fits the cylinder. Tow or soft rope, saturated with grease, is carefully wound round the cylindrical body of the piston, between the upper plate and lower flange; the former is then drawn up by screws, compressing the intervening packing till it perfectly fits the cylinder, and yet by its elasticity allows of its adapting itself to the inequalities in the surface. The first (*fig.* 2) of the annexed figures will explain the details of the construction of the ordinary piston.

Fig. 2.

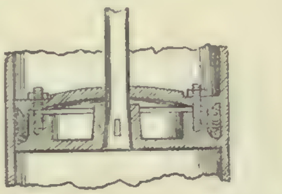


Fig. 3.

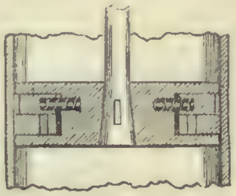
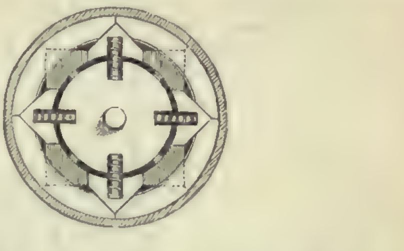


Fig. 4.



But as the friction of this common piston is necessarily very considerable, the better class of engines have usually what are called *metallic pistons*, of which there are different kinds, invented by Cartwright, Jessop, Barton, and others. The body of these pistons is metal, made in pieces or segments, acted on by springs radiating from a centre; so that while the friction is diminished by both surfaces being metallic, the piston, owing to its construction, can adapt itself to the irregularities of the cylinder. It is found in practice that these metallic pistons wear for a long time, and do not of course require the frequent repacking necessary to those with tow or hempen stuffing. *Figs.* 3 and 4 represent a plan and elevation of an improved form of Barton's piston, to explain the principle.

In Newcomen's engine the steam was admitted to the cylinder, and the communication again cut off by means of a cock of the common construction; but a more efficient contrivance is requisite when the steam is to be admitted alternately both above and below the piston, and to the condenser, as it is in engines since the introduction of

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* One cubic inch of water occupies 1711 cubic inches of space, in the form of steam at 212°; consequently, the space occupied by the water after the condensation may be neglected in the computation.

Watt's improvements. This can be accomplished by a *four-passage cock*, originally invented by Leupold in 1720, and since improved by Bramah and others. The principle of a four-way cock will be understood by the annexed figure (*fig.* 5) of the plan of one employed by Messrs. Maudslay and Field in their small engines.

Fig. 5.

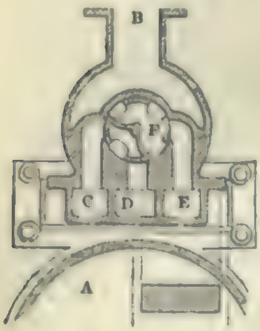
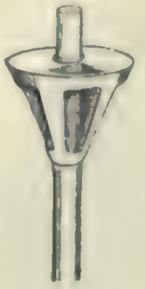


Fig. 6.

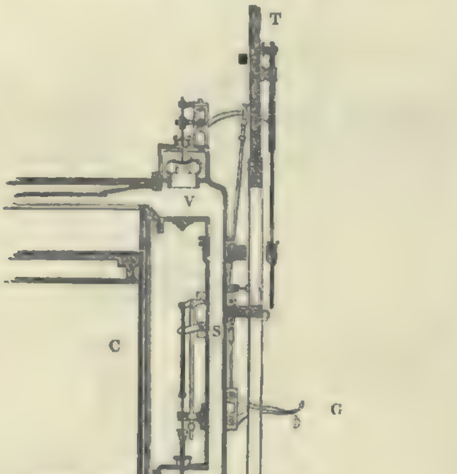


A is a portion of the cylinder; B, the steam-pipe; C, D, E, three passages, one communicating with the top, another with the bottom of the cylinder, and the third with the condenser; F is the four-passage cock, which, by turning alternately to the right and left, establishes a communication between one of the former with the latter passage. *Fig.* 6 represents the conical valve with its side apertures, and that at the top, by which the steam enters.

Watt employed flat conical valves for the purpose under consideration, which were raised or depressed by cranks acting on a guide-rod at right angles to the plane of the valve, which therefore did not turn on a hinge like the common *clack-valve* of a pump. In some of his engines the valves were raised or depressed by toothed sectors acting on a rack in the guide-rod, so that the valve might rise from its seat without altering the parallelism of its plane. Two such valves were mounted in one box, one above the other, the guide-rod of the lowest passing through that of the upper.

Fig. 7 shows the valves of this construction, of the large engine erected by Messrs. Maudslay for the Chelsea Water-Works. C, part of the cylinder; P, the piston; T, the "plug-tree;" G, the gearing handles, which are struck by the tappets on the plug-tree, and thus open and close the valves V; S, the steam-passage to the upper and lower parts of the cylinder; D, the passage to the condenser.

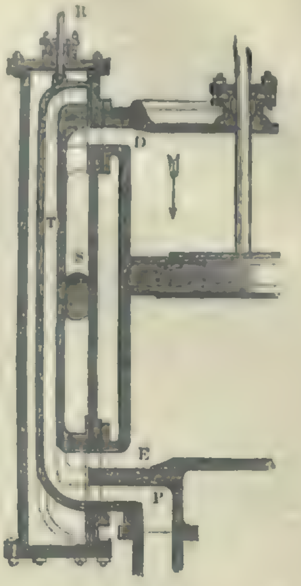
Fig. 7.



In most engines of the present day, however, the *slide-valve*, as it is termed, has superseded the use of the others, excepting in large pumping-engines: a perfectly flat surface slides on another, terminating the orifices which are to be opened and shut; such is the general principle, but the forms and arrangements are too numerous to be mentioned. *Fig.* 8 shows a part of the cylinder of an engine with *box-slide valves*, now much used.

S, the orifice of the steam-pipe; the steam passes to the upper part of the cylinder at D, the lower passage E being shut off in the position of the valve shown and shaded in the figure; the slide is moved by the rod R, and it is shown in its second position in dotted lines, in which position it will be seen that the steam can then enter *beneath* the piston, while the passage P to the condenser is in turn in communication with the upper part of the cylinder by means of the tube T of the slide.

Fig. 8.



The characteristic and most valuable part of this principle is this, of making part of the slide act as a pipe to connect the two parts of the cylinder alternately with the condenser. The steam, by pressing on the slide in the common form of slide, enormously increases the friction with the surface against which it acts, and also produces rapid wear of the parts; this defect is remedied in the box-slide and all others which possess this peculiarity.

Slide-valves were proposed by Murray, in 1799, but were abandoned, till improved workmanship allowed of their being more perfectly made; they have been successively improved in principle by Murdoch, Bramah, Millington, Maudslay, and Seward, the slides of the last-named being now much used in marine engines.

It has been mentioned that the alternate action of the valves in the atmospheric and Watt's engines was produced by pins, or *tappets*, adjusted on a rod called the *plug-tree*, suspended from the beam; as the plug-tree moved up and down with the beam, the tappets struck the ends of bent levers or cranks, which raised or depressed the valves in proper succession: some of these levers were so formed that the tappet by pressing against them might keep the valve closed during the greater part of the stroke* of the piston, and others required an intermediate shorter lever, or claw, to act on the valve-rod; so that the whole arrangement was inevitably complicated and cumbrous. But when the slide-valve superseded Watt's double conical valves, and the steam passages could be opened and closed by the motion of one rod only, connected with the slide, this motion could be readily produced by what is termed an *excentric*, which for this purpose usually consists of a circular plate of metal, keyed *excentrically* on the shaft of the fly-wheel, and working within a ring attached to the end of a frame intended to move a crank directly connected with the slide-rod at its other extremity. As the shaft revolves, the excentric plate imparts an alternating motion to the frame, which, transmitted by the crank, alternately raises and depresses the slide-rod. The principle of the excentric is one of the most valuable of those mechanical contrivances by means of which a continuous circular can be converted into an alternating rectilinear motion.

The "beam" so frequently alluded to, was obviously the readiest mode of connecting the alternating motion of the piston with the pump to be worked, in the atmospheric engine; and owing to the facilities it offers of working the plug-tree and the three pumps necessary in Watt's condensing engines, continued to form a part of the arrangement whether the engine were intended to pump a mine or to drive machinery. The beams of the first engines were made of two or more trees, bolted together to obtain the requisite rigidity, and further strengthened by a kind of truss, as is seen in the diagram of Newcomen's engine. But when the art of making heavy iron-castings was perfected, that metal was substituted for wood, to the manifest improvement of the engine in every respect. Watt also removed the cumbrous arched heads, which had been previously employed for the purpose of causing the piston-rod to move up and down in the same right line, though connected with the end of the beam, which necessarily described an arc of a circle, as turning on a fixed centre; this arrangement implied the use of a flexible chain, to suspend the piston, which might wind round, and unwind from, the arch, but a chain could not be used when the piston had to raise the beam, as it had to do in Watt's engine, instead of being raised by it, as in Newcomen's.

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* The term *stroke* is technically used by engineers to express the whole motion of the piston from the top to the bottom of the cylinder and back again.

The object of these "arched heads" is attained in modern engines by a system of simple rods or levers, so combined that one point may move in a straight line nearly. There are a variety of combinations by which this may be effected, but that termed the "parallel motion," invented by Mr. Watt for the purpose, is the only one which need be here noticed, as being that most commonly used.

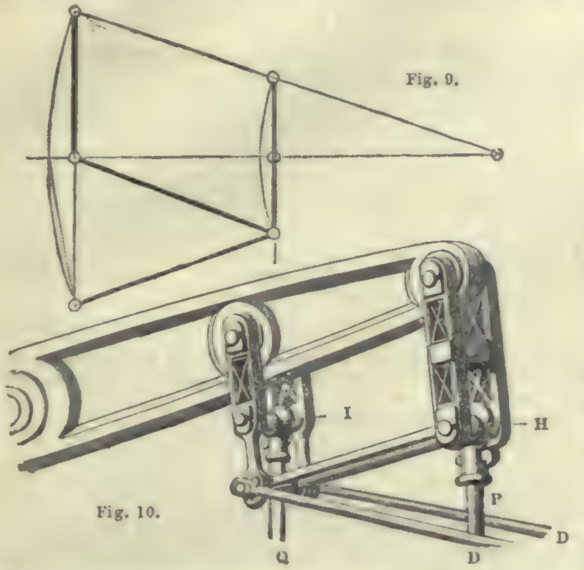

Fig. 9.

Fig. 10.

The geometrical principle of this motion is shown in *figs.* 9 and 10 as well as the whole arrangement when the piston is near the top of the cylinder: D D are rods fixed by one end to the frame supporting the beam, while the three other pair of levers being jointed together and to the beam, must obviously, in every position, form a parallelopipedon, whence the name is derived; P is the piston-rod attached to H; Q that of the hot-water pump connected with the parallel motion at I in the centre of that side.

When the engine is employed to drive machinery of any kind, a *fly-wheel* becomes a necessary adjunct to it. A fly-wheel is one in which the principal quantity of the matter is distributed in the periphery; when such a wheel revolves on an axis perpendicular to its plane, the greatest quantity of matter moving with a maximum velocity, the momentum of the whole is a maximum, while its inertia, if it be large, causes it to control, or equalise, the motion of the machinery through which it receives its own. It is the momentum of such a wheel which constitutes the disposable force available for the multifarious purposes to which machinery can be applied; so that in the case of the steam-engine, although the elasticity of steam is the original source of power, the immediate one by which the work is executed is the momentum of the fly-wheel.

It is consequently necessary to adapt some contrivance to the end of the beam, which shall convert the alternating circular motion of the latter into a continuous one of the fly-wheel; this is effected by the *rod* and *crank*, a piece of mechanism of such frequent occurrence that it is unnecessary to describe it; the treadle of a lathe is a familiar instance of its application, and for a similar purpose, that of connecting the alternate motion of the turner's foot with the continuous one of the wheel of the lathe; the principle of the treadle, or rod and crank, is in fact the only one by which an alternating can be converted into a continuous circular motion; it must therefore be employed, notwithstanding the variation in the power transmitted by means of it, consequent on that of the angle formed by the rod and crank with each other. Thus, for example, when the rod and crank are in the same direction, which occurs twice at every rotation, no force whatever is transmitted by it, and the primary one is entirely suspended or held in equilibrium by the resistance of the fixed centres on which the crank and rod turn.

In the steam-engine the rod and crank are so adjusted that these two neutral positions occur when the piston is at one or the other end of the cylinder, and the valves are so arranged that, both steam passages being closed, all communication between the engine and the boiler is cut off; otherwise the steam, which could not under these circumstances move the piston, would exert its force to the detriment of the machine; as soon, however, as the momentum of the fly-wheel has carried the crank past these positions, the motion reciprocally imparted through it to the piston and valves admits the entrance of the steam from the boiler into the cylinder again. It is one of the important details in the construction of the engine, that the piston should be in that point of its course when the steam exerts its maximum of effect on it, at the time when, the rod and crank being at right angles to each other, the maximum of force may be exerted to turn the fly-wheel.

Since the diameter of the circle described by the crank must be equal to the length of the stroke, or to the distance through which the piston moves, it might be thought advantageous to increase the length of the stroke, as admitting of a longer crank; but there are limits to this length, determined by a variety of circumstances, some of which will be hereafter explained.

When Watt substituted the elastic force of steam for the pressure of the atmosphere, he introduced a source of power which might be increased to an indefinite extent, provided it were found advantageous to employ it; and the question naturally suggests itself, what is the elastic force or pressure at which the maximum of useful effect can be produced with a minimum expenditure of fuel? Unfortunately no direct answer can be given; in mathematical language, the unknown quantity is a function of too many variables to be capable of determination, except by repeated experiments for every specific engine, this quantity varying with the principle of its construction, even with the details. The results of such experiments seem to show, that generally it is more advantageous to employ steam of a comparatively high elastic force; accordingly the pressure was increased, in engines constructed by Watt, from 4 to 8 or even 12 lbs. on the inch, the apprehension of danger from the explosion of boilers in which steam of high pressure was generated constituting the chief limit to a further extension of the practice; at the present day condensing engines are even worked as high as from 25 to 30 lbs. pressure. The nature of those improvements in the construction of boilers will be briefly explained hereafter, by which steam of 200 lbs. on the inch may be generated, if requisite, with nearly as much security as that of 4 lbs. in the earlier boilers; but at present, simply stating that such is the case, we proceed to explain some important changes which have been consequently made in the principles of the engine.

When the steam is first admitted into the cylinder, the total space filled by the steam is immediately augmented by that through which the piston moves; and if the capacity of the boiler were not several times greater than that of the cylinder, the consequence would be a gradual diminution of the pressure, supposing the total quantity to remain the same: but the moment the pressure in the boiler tends to diminish, an additional quantity of water passes into the state of vapour, of the same tension as that previously generated, provided the temperature be maintained; hence the pressure on the piston may be regarded as sensibly the same throughout the whole of its stroke, provided that pressure be somewhat greater than that of the atmosphere, and the communication with the boiler remain open. It must not, however, be supposed that the pressure on the piston is the same with that of the steam in the boiler; all that is here asserted is that the pressure on the former will be uniform.

But if the pressure be considerably greater than that of the atmosphere, the steam, even when separated from the water, while expanding in the enlarging space formed by the motion of the piston, will exert sufficient force to continue that motion, till at last the pressure diminishing inversely as the space increases, and directly as the temperature, according to Mariotte's and Gay-Lussac's laws, that pressure will finally be not in equilibrium with the resistance, and all motion will cease. This is the important principle of working engines, originally proposed by Watt, though not employed by him, but which now, from the improvements in boilers above alluded to, is becoming general under the name of that of *expansion*. In the common engine, if the pressure on the piston continue uniform during the stroke, as it would do if the communication with the boiler remained open, the piston would move with an accelerating velocity till it arrived at the end of the cylinder, when the motion in that direction being suddenly stopped, the momentum must be expended on some of the fixed points of the machine, to its manifest injury, and with the useless expenditure of so much power; accordingly the communication with the boiler is now always cut off when the piston has arrived at a certain point, and with a momentum sufficient to carry it to the end of its stroke without any useless expenditure of force, while the steam behind it, which was originally of but a few pounds pressure above that of the atmosphere, thus limited in quantity, rapidly declines in force, and ceases to urge the piston on. But on the "expansion principle," when the steam possesses considerable elastic force, the communication with the boiler may be cut off much sooner, and the piston is urged forward by the expansive force of the steam, which, although decreasing as the space increases, is yet sufficient to carry the piston to the end of the stroke.

If it be asked how it is advantageous to use half the quantity of steam at twice the pressure, when it takes perhaps twice the quantity of fuel to raise the steam to the double pressure, the answer is, that it can be shown analytically that the total force exerted by steam acting expansively is greater than that which would be exerted by steam of a constant pressure, equal to the mean of those exerted, first, at the moment the steam-valve is closed, and, secondly, when the piston arrives at the end of its stroke; consequently, as less steam may be used to produce the required effect, a saving of fuel is the result, or in other words, the quantity of steam may be much less than half, at double the pressure, or the pressure much less than doubled, to produce the same effect.

As long as a continued force of any kind produces a continued motion with a constant velocity in any body, the force must be in equilibrium with the resistance it has to overcome; for if the force were greater than the resistance, it would produce an accelerating motion, which is contrary to the supposition: and if the resistance became greater than the force, the velocity would retard till the equilibrium were produced: as long, therefore, as a steam-engine is moving with a constant velocity, the *pressure on the piston* must be equal to the resistance to be overcome, consisting of the net work to be done, together with the friction of the various parts, the resistance of the uncondensed steam, of the air on the opposite side of the piston, and of other sources of resistance, which all concur to produce the gross resistance to be overcome. Putting P' for the pressure of the steam on each unit of surface of the piston, and R for the resistance for the same unit, or for the quotient obtained by dividing the total resistance by the number of units of surface, we have

$$P' = R \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (A)$$

as the first equation of condition; but since the velocity of the motion must be taken into consideration, when the *power* or force of the engine is to be determined, we must consider the velocity with which this pressure is applied, or, in other words, the rate at which the steam is applied to the cylinder; and it is obvious that when the engine is moving with a constant velocity, the supply to the piston must be exactly that produced in the same time by the evaporation going on in the boiler. If, therefore, S expresses the volume of *water* evaporated in a unit of time and transmitted to the cylinder, and m the ratio of the volume of *steam*, formed under the pressure P in the boiler, to the volume of *water* which produced it, mS would express the volume of steam generated in each unit of time under the pressure P: by passing into the cylinder this steam assumes the pressure P', and, neglecting the further change produced by the variation in the temperature of steam in changing from pressure P to pressure P', the volume of that quantity of steam would be inversely as the pressures by Mariotte's law; consequently the volume mS, when transferred to the cylinder, would become $mS\frac{P}{P'}$; and putting v for the velocity of the piston and a for its area, av will be the volume of steam expended in each unit of time; hence we get

$$av = mS\,\frac{P}{P'} \quad . \quad . \quad . \quad . \quad . \quad . \quad (B)$$

eliminating P' between equations (A) and (B), we obtain

$$v = \frac{mS}{a} \cdot \frac{P}{R}$$

$$R = \frac{mSP}{av}$$

$$S = \frac{avR}{mP}$$

for the *velocity*, *resistance*, and *evaporation*, when the other quantities are known; it must be observed, however, that the element neglected in these general deductions, namely, the change produced by the variation in temperature, has an important influence on the result, and must therefore now be taken into account.

$$\mu = \frac{1}{n + qp} \quad . \quad . \quad . \quad . \quad . \quad . \quad (C)$$

is the general expression for the steam during its action in the engine, μ being the volume, and p the pressure, and n and q constants, determined by experiments, for different kinds of engines.[*]

Let a certain volume of *water*, S, be converted into steam of the pressure p, and let M represent the volume of *steam* produced, then—

$$\mu = \frac{M}{S} = \frac{1}{n + qp};$$

if M' and p' stand for the volume and pressure of steam from the same volume of water S, under other conditions, then—

$$\mu' = \frac{M'}{S} = \frac{1}{n + qp'};$$

and therefore the ratio of the volumes of steam produced under these different conditions from the same volume of water will be—

$$\frac{M}{M'} = \frac{\frac{n}{q} + p'}{\frac{n}{q} + q} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (D)$$

that is, the volumes will not be inversely as the pressures simply, according to Mariotte's law; but inversely as the pressures augmented by a constant.

From the above equation we get—

$$p = \frac{M'}{M}\left(\frac{n}{q} + p'\right) - \frac{n}{q} \quad . \quad . \quad . \quad . \quad (E)$$

Let P = pressure of the steam in the boiler.
P' = pressure of the steam in the cylinder; $P' < P$ *generally*.
π = pressure at any instant when acting *expansively* in the engine.
l = length of the stroke.
l' = the length of that part of stroke performed before the communication between the boiler and cylinder is cut off.
λ = the length of that portion of the stroke performed when the pressure is become π.
a = area of piston.
c = *clearage*, or space in the cylinder at each end left between the piston and the ends of the cylinder, including the part of the steam-pipe between the slide-valve and the cylinder, which space is necessarily filled with steam at each stroke.

When the piston has performed λ of its course under the expansive force of the steam, let $d \,.\, \lambda$ be the differential of this length, then the corresponding *force* or effect will be $\pi a d \,.\, \lambda$: and at the same instant the space $a(l'+c)$ occupied by the steam before the expansion will become $a(\lambda+c)$. Hence from (E)—

$$\pi = \left(\frac{n}{q} + P'\right)\frac{l'+c}{\lambda+c} - \frac{n}{q};$$

$$\text{and} \quad \pi a d \,.\, \lambda = a(l'+c)\left(\frac{n}{q} + P'\right)\frac{d \,.\, \lambda}{\lambda + c} - \frac{n}{q}\, a d \,.\, \lambda.$$

Integrating between the limits l' and l, we obtain

$$a(l'+c)\left(\frac{n}{q} + P'\right)\log\frac{l+c}{l'+c} - \frac{n}{q}\,a(l-l')$$

for the value of the total effect produced by *expansion* from the moment when the communication with the boiler is cut off, to the end of the stroke. By adding to this therefore the effect $P'al'$, produced previously, we get

$$a(l'+c)\left(\frac{n}{q} + P'\right)\left[\frac{l'}{l'+c} + \log\frac{l+c}{l'+c}\right] - \frac{n}{q}\,al = aRl \quad . \quad . \quad (F)$$

If in this expression, $l'=l$, which is equivalent to supposing the engine to be working without expansion, we get $P'=R$, as it ought to be.

Resuming the equation $\frac{S}{n+qP'}$, which expresses the volume of steam at the pressure P' furnished by the boiler in the unit of time, and $a(l'+c)$ being the volume of this steam expended at each stroke; then if there are K strokes in that time, the expenditure of steam will be

$$Ka(l'+c);$$

and if v be put for the velocity of the piston, we have $v=Kl$, or $K=\frac{v}{l}$; hence, by substitution, the expenditure will be

$$\frac{va(l'+c)}{l} = \frac{S}{n+qP'} \quad . \quad . \quad . \quad . \quad . \quad (G)$$

by equating the expenditure to the volume furnished by the boiler, which, as has been above stated, must be the condition when the

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[*] It can be shown that the density and relative volume of a vapour, whether or not in contact with the liquid, may be deduced, if its pressure and temperature are known; and that when in contact with the liquid, the temperature varies directly with the pressure. In deducing formulæ for the steam-engine, it is necessary to be able to determine an expression for the relative volume of the steam in contact with the water, or the volume of the steam at the maximum of density and pressure at any proposed temperature. Now this cannot be done from the existing formulæ for analytical reasons, and it becomes necessary to adopt some empirical formula, for determining this relative volume of steam at its maximum of density, in terms of its pressure only; this formula must be tested by its conformity with experiment. The late M. Navier proposed for this purpose,

$$\mu = \frac{1000}{0{\cdot}09 + 0{\cdot}0000484\,p}$$

in which μ is the ratio of the volume of steam to an equal weight of water, and p the pressure; but this formula, though true within certain limits of pressure, is not consistent with experiments at pressures lower than the atmospheric, and the following is propounded by M. de Pambour, as more correct and comprehensive:—

$$\mu = \frac{10000}{0{\cdot}4227 + 0{\cdot}00258\,p} \text{ for condensing engines;}$$

$$\mu = \frac{10000}{1{\cdot}421 + 0{\cdot}0023\,p} \text{ for non-condensing engines;}$$

p being the pressure in pounds on the square foot. These formulæ in general terms therefore are expressed by

$$\mu = \frac{1}{n + qp} \text{ as in the text.}$$

motion is uniform. Eliminating P' between (F) and (G), we get for the final general equation—

$$v = \frac{\text{S}}{a} \cdot \frac{1}{n + q\text{R}} \left[\frac{l}{l' + c} + \log \frac{l + c}{l' + c} \right] \quad . \; . \; . \; (\text{H})$$

The resistance expressed by R in this formula is the *total* pressure on each unit of surface of the opposite side of the piston, and is composed of three parts. First, of the *load*, or work to be moved or done, which we will denote by r. Secondly, of the resistance arising from the friction of the engine, which may be expressed by $f + \delta r$; f being the friction when there is no load, and δr the increment due to the additional friction for each unit of the load r. And, lastly, of the pressure on the opposite surface of the piston, which will be the atmospheric pressure in non-condensing engines, or that of the uncondensed steam and residue of air in condensing ones; this we shall call p. All these, r, $f + \delta r$, and p, refer only to each unit of surface of the piston, or

$$\text{R} = (1 + \delta)\, r + p + f,$$

by substituting this value for R in (H), and putting k for

$$\left[\frac{l}{l' + c} + \log \frac{l + c}{l' + c} \right],$$

we obtain

$$v = \frac{\text{S}}{a} \cdot \frac{k}{n + q\,[(1 + \delta)\, r + p + f]} \quad . \; . \; . \; (\text{K})$$

Now the quantity $\frac{\text{S}}{n + q\text{R}}$, it will be seen (C) is the total space occupied by the steam (in contact with the water), under the pressure R: hence to deduce the velocity v, the volume of steam corresponding to the volume of water S, supposed to be converted into steam under a pressure equal to R, must be calculated; and this volume being divided by a, the area of the piston must be multiplied by k.

The equation thus deduced shows the relation between all the quantities, known or sought, that enter into the mechanical theory of the engine in its most general form: it should be observed however that to preserve homogeneity, the dimensions a, l, l', should be expressed in the same unit as the volume S of the water evaporated; and the pressures P, r, and p referred to the same unit as S.

When this formula is used for computation, it must be understood that the quantity S expresses the *effective* evaporation; that is, the volume of water which really passes to the cylinder in the form of steam, and which acts on the piston, and does not allow for any loss by leakage or from any peculiarity in the structure of the engine.

If the engine be a condensing one, acting expansively, l' must be made equal the length at which the steam is cut off; if expansion be not employed, l' must be made equal to l, or to the whole length of the stroke, in which case the quantity k becomes $\frac{l}{l + c}$, and the expression for the velocity becomes

$$v = \frac{\text{S}}{a} \cdot \frac{l}{n + q\text{R}} \cdot \frac{1}{l + c}.$$

The part p of the quantity R must be made equal the pressure of the uncondensed steam, &c. If the engine be a non-condensing one, then p will be equal the atmospheric pressure.

Since from (K) we obtain

$$ar = \frac{\text{S}k}{(1 + \delta)\, qv} - \frac{a}{1 + \delta} \left(\frac{n}{q} + p + f \right) \quad . \; . \; (\text{L})$$

it might be supposed that when $v = 0$, the resistance would be infinite, a paradox which would appear to vitiate the correctness of the formula. But it must be borne in mind that when $v = 0$, $\text{S} = 0$; for S is the quantity of steam which passes through the cylinder in each unit of time: and since no quantity of steam, however small, can pass without moving the piston, as long as S has any real value, v will have one too: when therefore $v = 0$, $\text{S} = 0$ also; and then

$$ar = \frac{0}{0}, \text{ and not} = \infty;$$

that is, the formula becomes indeterminate, but not the less direct, as will appear by considering the other quantities it involves, and the consequences of putting $v = 0$.

By supposing the velocity zero, it is, in the first place, evident that no steam can pass to the cylinder, as has been stated; consequently there can be no expansion, that is, $l = l'$. Again, the velocity being zero, the piston at rest becomes equivalent to the fixed sides of the boiler, and the pressure it sustains is equal to that in the boiler.

The working of an engine may be considered under three conditions: first, when it is working with a given pressure of steam, and with any, whatever, load or velocity. Secondly, when it is working with a given pressure, and with that load or velocity compatible with the production of a maximum of useful or net force with that pressure: this may be termed the *relative maximum of useful effect.* And thirdly, when the pressure having been determined to furnish the force most consonant with the action of steam in any specific engine, the load is regulated so as to be that most advantageous for that pressure: this last constitutes the *absolute maximum of useful effect* for that machine.

The three fundamental problems for solution in the calculation of steam-engines consist in determining the velocity, the load, and the rate of evaporation in the boiler, since the useful effect, or net available power, is a function of these three quantities; and this net available power may be expressed in six different ways:—

First, by the number of pounds raised to a unit of height in a unit of time.

Secondly, by what is termed the "horse-power" of the engine.

Thirdly, by the weight raised by the consumption of 1lb. of fuel.

Fourthly, by the weight raised by the evaporation of a cubic foot of water.

Fifthly, by the number of pounds of fuel, or of cubic feet of water, for each horse-power.

Sixthly, by the number of horses-power which is furnished by each pound of fuel, or by each foot of water.

For the various formulæ by which all these problems may be numerically solved for different kinds of engines, and for the investigations by which those formulæ are deduced, we must refer to more comprehensive works; contenting ourselves here with deducing the general equations for the other unknown quantities of evaporation, useful effect, and horse-power, as we have done for velocity.

From (K) we obtain

$$\text{S} = av \frac{n + q[(1 + \delta) r + p + f]}{k} \quad . \; . \; . \; (\text{M})$$

as the expression for the evaporation of which an engine must be capable to overcome a given resistance r, with a proposed velocity v, S being the quantity of water which is to be converted into steam and transmitted to the cylinder in each unit of time.

The useful or net force of the engine generated in the same unit of time is obviously arv; since v, the velocity, is in fact the space moved through by the piston in that time; by multiplying therefore both sides of (L) by v we obtain

$$\text{Useful force} = arv = \frac{\text{S}k}{(1 + \delta) q} - \frac{av}{1 + \delta} \left[\frac{n}{q} + p + f \right] \quad . \; . \; (\text{N}_1) \text{ or by}$$

multiplying both sides of (K) by ar, we obtain an expression for the same quantity in terms of the load

$$\text{Useful force} = arv = \frac{\text{S}rk}{n + q[(1 + \delta) r + p + f]} \quad . \; . \; (\text{N}_2)$$

It will be noticed that for any proposed engine this force does not depend on the pressure of the steam in the boiler, P not entering into these expressions; but on the evaporation S effected in the boiler in each unit of time.

What is termed a "horse-power" is estimated as 33,000 lbs. raised one foot in a minute [HORSE POWER]: by dividing therefore the equations last obtained by 33,000, we get

$$\text{Useful force in horse-power} = \frac{\text{Useful Force}}{33000}.$$

and if during the unit of time N lbs. of coals are used in the furnace,

$$\text{Useful force from 1 lb. of fuel} = \frac{\text{Useful force}}{\text{N}}$$

We must now return to our general description of the engine and of its modifications.

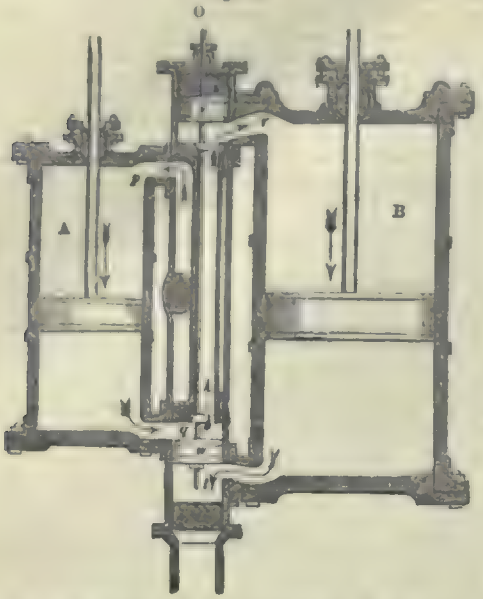
In 1781 an engineer named Hornblower proposed using the expansive principle by means of a double cylinder, but was prevented from carrying out his plan by the comprehensive and jealously guarded patents of Watt and his partners. In 1804, however, Woolf brought this principle of the double-cylinder engine into use. The annexed figure (*fig.* 11) will explain the mode of its action with an improved slide-valve.

The steam enters through the passage p *above* the piston in the smaller cylinder A, at a considerable pressure: while the piston is descending under its influence, the steam from beneath passes through the tube r *above* the piston in the large cylinder B, which is impelled downwards by its expansion, the steam which was previously under this piston having passed to the condenser by the passage t. When the stroke is completed, the slide is moved downwards by its rod o. The small plugs or pistons v and w pass below the openings r and t, and the slide below the orifices p and q, and the action is reversed.

But though possessing considerable advantages, the double-cylinder engine has not become common, unless in the case of large pumping engines, probably owing to the complication of its structure, and the increased effects of radiation from so large a surface, more than compensating its merits; and the expansive principle, equally applicable to a single cylinder, is now principally employed in engines of the common construction.

To reduce the compass and weight of the engine sufficiently to render it portable, the cumbrous apparatus of the condenser, and its attendant pumps and cisterns, had to be discarded; and since the principle of condensation was consequently renounced, it was necessary to raise the steam to a pressure sufficient to overcome that of the atmosphere on the opposite side of the piston. To allow the steam to act alternately on both sides of the piston, that which had just acted on one side to drive the piston was expelled into the open air through an orifice, corresponding to that which would have connected the cylinder with the condenser in an engine of the usual construction; but unless this orifice were as large as the diameter of the cylinder, which obviously it never can be, the steam, retarded in its escape by the contraction of the passage, must diminish, by its resistance to compression, the effective force of that which is acting to impel the piston.

Fig. 11.



Such is the simple principle, and such the greatest defect, of the non-condensing engine; but the saving in original cost and the paramount advantage of portability more than compensate for this defect; so that the use of this kind of engine has become general, not only for the purposes of locomotion, but for a variety of others where the engine is stationary, and probably in many instances where its advantages are imaginary.

Since the pumps of the condensing engine are dispensed with in the non-condensing one, the beam may be so likewise; the piston-rod is made to move in a straight line, by having a cross-piece attached at its top, which slides between *guides* fixed on each side of the cylinder, the rod which works the crank of the fly-wheel being attached to the end of this cross-piece. A still further simplification is effected by connecting the piston-rod directly with the crank on the shaft of the fly-wheel, the cylinder being mounted so as to oscillate as the wheel revolves on the steam passage, and thus alternately to open and close the communication between the top and bottom of the cylinder. Such engines are termed *vibratory*, and are successfully used where space must be economised, as with marine engines, but the weight of the cylinder thus moved is so much to be deducted from the power of the engine, and further causes a rapid wear of the centres on which it turns, which consequently cannot be long preserved steam-tight, and require frequent renewal.

Steam-engines are properly classed, according to the principle on which the physical properties of the steam are employed in them, into—

1. *Condensing Engines.*

1. Atmospheric engines, acting by	Condensation only.
2. Double-acting engines . . .	Pressure and condensation.
3. Double-acting engines . . .	Pressure, expansion, and condensation.

2. *Non-condensing Engines.*

1. Engines worked by	Pressure only.
2. Engines worked by	Pressure and expansion.

The form of the engine, the arrangement and construction of its parts, its power, &c., depend entirely on the purpose to which it is to be applied, and may be indefinitely diversified, but those most in use may be artificially classed thus—

1. *Condensing engines*, with beams and parallel motions.
   1. Without a fly-wheel, for pumping in mines, &c.
   2. „ „ Marine engines.
   3. With a fly-wheel, for working machinery.
2. *Non-condensing engines*, without a beam.
   1. Stationary, with a fly-wheel for working machinery.
   2. „ Rotatory engines.
   3. Locomotive engines, without a fly-wheel.

Marine engines, or those used for propelling vessels, are in this country generally condensing engines, their situation admitting the abundant use of cold water. The principal peculiarity in the arrangement of the marine engine is the position of the beam, which, for the purpose of economising room, is placed lower than the cylinder, and is double, there being one on each side; a rod from one end of each of these is connected with a cross-piece at the top of the piston-rod, the rectilinear motion of which is produced either by guides, or by a crank-arrangement, analogous in its action to the parallel motion. The other ends of the double beam are connected by a cross-piece, carrying in its centre the "rod" to work the crank on the shaft of the paddles. In all vessels of any magnitude, there are two engines complete, so arranged that while the rod and crank of one are in their neutral position, those of the other are in that of greatest effect. Two engines are necessary to equalise and continue the motion of the wheels; for in the marine engine, the paddles, instead of performing the part of fly-wheels to continue and control the motion of the piston, require the whole force of the engines to maintain their own motion, owing to the resistance they have to overcome. There is also this further advantage derived from two engines, that if one should be injured, the vessel may be still propelled by the other, and not be entirely dependent on her sails, as she would otherwise be.

It has been mentioned that there is a limit to the proportion between the diameter and length of the cylinder; the advantage that would accrue in gain of power by a long stroke being diminished by the greater radiation of heat from the larger surface diminishing the force of the steam in the cylinder; here therefore, as in every other calculation connected with the steam-engine, it is hardly possible to arrive at any formula or rule that can be invariably used. If the surface of the cylinder were to be made a minimum, with a maximum of capacity, we could readily determine that the length should be twice the diameter;[*] but we find that this proportion is not adhered to by the best makers; it varies from 3 : 1 to 2 : 1; but in the marine engine it is usually shorter; in some instances the proportion is 1 : 1·25.

The diameter of the cylinder of a marine-engine is usually greater, in proportion to its length, than it is in others, in order to obtain, by an increased surface of piston, that power which is unattainable by a long stroke, owing to the limited space which can be appropriated to the engine. Formerly, the apprehension of danger, where so many lives were at stake, prevented the use of steam of more than 4 to 6 lbs. on the inch in marine engines, and the expansion principle consequently could not be had recourse to. At present, the economy of using this principle has outweighed the apprehension in the minds of the owners of vessels, while the public, contented with the information that the engine is a condensing one, seldom inquire further, and conceive that the steam is at a low pressure in all marine engines, although, where the expansion principle is used, which it now extensively is, the pressure in the boiler is at about 30 lbs. on the inch above the pressure of the atmosphere.[†]

Engineers have always been induced, by the obvious advantage of a continuous over an alternating motion, to aim at contriving a steam-engine in which the steam should act directly to produce such a motion. It does indeed appear at first sight that, where the object of the engine is to produce a continuous circular motion of a fly-wheel, or of wheels of some kind, it would be desirable that the steam should be applied directly to impel the wheel, instead of having its force transmitted through a series of levers, necessarily increasing the friction and the cost of the engine. Watt accordingly patented more than one of such rotatory engines, and many others since have from time to time brought forward arrangements for the purpose, but none have come into permanent and general use. The fact is that, as can be easily shown, the employment of steam in this way is productive of a greater waste of power, with a greater increase of friction, than can be compensated by any real advantages. In all rotatory steam-engines

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[*] Let l = length, x = the diameter, c = the capacity of the cylinder; since the concave surface is only gradually brought into contact with the steam, by the motion of the piston, its effects on the temperature may be considered as about half what it would be if the whole surface were at once exposed. Then the whole surface, including the two ends, being

$$\pi x l + 2\,\frac{\pi x^2}{4} \text{ and } c = \frac{\pi l x^2}{4},$$

we have for the surface affecting the temperature of the steam

$$\frac{\pi x l + \pi x^2}{2} = \frac{2c}{x} + \frac{\pi x^2}{2}$$

therefore

$$\pi x dx - \frac{2c dx}{x^2} = 0$$

and by substituting the value of c, and reducing $2x = l$.

[†] On the Mississippi the boat-engines are worked with steam of from 100 lbs. to 130 lbs. on the inch; but the latter enormous pressure is rarely exceeded, "except," as an American commander said, "on *extraordinary occasions.*"

hitherto proposed, the principle has been to admit the steam to act on a fan or fans revolving round an axis of the cylinder; and, by ingenious excentric movements, the surface of these fans is made to increase as the steam diminishes in elastic force from the enlargement of the space it occupies. Many such engines have been used for a time, but commonly after a few years' trial they have been abandoned, and the reciprocating principle substituted, thus proving that experience confirmed the deductions from theory.

In all mechanical combinations, the object to be effected necessitates a certain characteristic form of the machine, which it retains, whatever improvements may have been successively introduced either in its principle or in the details of its construction. We can recognise in a modern Sussex plough the general form of that used by the subjects of the Pharaohs to till the banks of the Nile; and Newcomen would acknowledge a marine engine made by Maudslay and Field as a descendant of his atmospheric one: but he would for some time be at a loss to tell the object of a locomotive engine of Stephenson's, if he could see it at rest only, and the connection between it and its tender would be beyond his comprehension. The reason of this is, that a locomotive engine is a perfectly new application of the power, having no other analogy to an ordinary engine except that steam is the source of power in both; but all locomotive engines will hereafter possess a family likeness.

The principal causes of this novelty of form are, that great velocity being the object, the boiler must constitute the greatest part of the bulk, in order to supply a sufficient quantity of steam to meet the demands of the two pistons making 200 strokes per minute, and even then it requires a *tender* to accompany it to carry a supply of fuel and water to keep up the quantity. The locomotion is usually produced by a pair of *driving-wheels* made to revolve by the engine by means of cranks on their axle, receiving motion almost directly from the piston-rods; the adhesion which takes place between these wheels and the edge-bars or rails, causes the carriage to move on, just as the paddle-wheels of a steam-boat propel the vessel by the resistance of the water to the float boards. The driving-wheels of a locomotive engine do not, any more than the paddle-wheels of a steam-boat, act as fly-wheels to regulate the velocity of the engine; this is effected in the former by the inertia of the whole mass; the great velocity consequently ensures the steady action of the engine. In the steam-boat this great velocity of the paddles is unattainable, and consequently two powerful engines are requisite to maintain even a moderate velocity; but air being the medium in which the driving-wheels of a locomotive engine act, almost any velocity can be imparted to them, and for obvious mechanical reasons is best attained by steam acting with a force almost amounting to impact on small pistons through a short stroke, two alternately acting cylinders being necessary, as in the steam-boat, to equalise the action of the cranks.

The two internal cylinders are most conveniently placed under the boiler in nearly a horizontal position; intermediate cranks preserve the rectilinear motion of the piston-rods, and connect them with the cranks on the axle; while excentric frames on this axle actuate the simple slide-valves required in a non-condensing engine. The steam which is driven out of the cylinder at each stroke, instead of escaping directly into the open air, passes into the funnel of the furnace, and thus increases the draught; but as the action of the engine cannot be understood independently of the boiler, it becomes necessary to turn our attention to that subject, without a general description of which, any account of the steam-engine would be incomplete.

Upon the South-Western Railway of England, and on the Chemins de Fer de l'Ouest of France, the engines employed are made with external cylinders, and the piston-head is connected with the crank fixed on the driving-wheel by a link or connecting-rod. There are great advantages in this system, so far as economy of construction is concerned; for the cranks are simply keyed on the ends of the axles of the driving-wheels, instead of being forged upon the axles themselves, and the whole of the machinery is of a simpler and more efficient character; but at the same time the condensation in the cylinders is far more serious than it would be in the case of internal cylinder engines, on account of the more exposed position of the external cylinder engines. The latter engines, it may be added, present the advantage of having a smaller dead weight, per horse-power exercised, than is the case with internal cylinder engines.

Since some of the principal objects to be kept in view in the construction of boilers are incompatible with each other, one or more must be dispensed with in order to secure the rest. The specific purpose for which the engine is constructed must determine the general principle of the boiler: thus, rapid generation of steam, security, compactness, and lightness must be aimed at in boilers for marine or locomotive engines, even at the cost of a comparative waste of fuel; while for those intended for pumping or driving machinery, economy of fuel must be the paramount object, the weight, form, and space occupied by the boiler being secondary considerations. And whenever steam of a high elastic force is to be used, that form of boiler should be adopted which will most nearly equalise the strain on it. The following requisites are therefore to be understood as being those which it would be desirable to combine, though, united, they are unattainable in practice.

First, the boiler should have the greatest capacity with the least surface, to save material, diminish the weight, and increase the strength: hence a spherical form would be best in this respect, but it is incompatible with an economical application of the heat to a great extent of surface, which is essential to the rapid generation of steam.

Secondly, the form should be as simple as possible, both for the sake of reducing the expense of construction and most readily admitting of repair. Boilers are made of iron or copper plates riveted together at their edges; and if one of these is cracked, or has been burnt, that plate can be taken out and another put in without pulling the whole to pieces, which must be done when the boiler is of a complex form; added to which, all angles are sources of weakness, owing to the inequality of the strain on the adjoining surfaces, and the injury done to the metal by bending it to form the angle.

The form of boiler used for Savery's, Blakey's, Newcomen's, and other engines of the 17th and 18th centuries, up to the time of Watt, was that of an inverted frustum of a cone, with a spherical top, and its bottom slightly concave. This boiler was set in brick-work like a common copper, the flame playing round the whole of the lower part. The steam-pipe was connected in the usual way to a flange of a collar in the spherical head. Watt adopted a long rectangular form, with a semi-cylindrical top; the ends were flat and upright, the sides slightly curved inwards, as was also the bottom. From this form it is termed the *waggon-head* boiler. It is set in a rectangular mass of masonry, the cylindrical head alone projecting above the level of the brick-work; the fire-place was underneath one end of the boiler, and extended backwards for one-third of its length; the flue, after proceeding to the further end, returned along one side, across the end, over the furnace, and along the other side into the chimney-shaft, the boiler itself everywhere forming one side of the flue, and consequently having the flame and heated air directly in contact with it at the bottom and sides. In some cases, when the boiler was very large, a cylindrical iron flue was formed through the boiler longitudinally, opening at each end into and forming a continuation of the brick one, thus increasing the surface to be acted on by the heat.

The next important modification in form was that of making the boiler entirely cylindrical with hemispherical ends, which is probably the form best fitted to combine as many requisites as possible. With this form the furnace is often placed in a second cylinder within the boiler, and forming the first part of the flue: thus the fuel being entirely surrounded by the water, little or no heat is lost by radiation; but there are serious objections to this practice on the score of accidents, as well as the deficiency in draught, owing to the confined space in which the combustion takes place.

When an engine is of such a size as to require more steam than one boiler of the ordinary magnitude can supply, it has two or more, set side by side, communicating with a common steam-pipe. Since the extent of surface exposed to the pressure of the steam, and therefore the liability to bursting, increases in a greater ratio than the capacity, there is obviously a limit to size, which can never safely be surpassed, while the security is proportionally increased by diminishing that capacity: hence the necessity for using two or more small boilers instead of one large one; and the principle, carried to its limit, constitutes that of the *tubular boiler*, in which the steam is generated in a series of independent metal pipes of small diameter, all communicating with a common steam-chamber or reservoir, itself small, and strong enough to resist great pressures.

These tubular boilers, however, have not come into general use, not only on account of their complexity, and consequent liability to derangement, but because, unless in the case of locomotives, or steam-boat engines, there does not exist any demand for steam of such high pressure as they are intended to generate.

Since, in accordance with the general hydrostatic law, every unit of surface of the boiler has to sustain the same pressure, if a small portion of that surface can be opened by the pressure of the steam, when it has attained that which the boiler was only intended to withstand, by the escape of a quantity of the vapour at this orifice, the elasticity of the remainder is again reduced below the limit. This is the object of the *safety-valve*, which is such an aperture, kept closed by a valve retained in its seat by a weight calculated to yield to, or be raised by, the pressure the moment the steam exceeds its proper elastic force.

The safety-valve was first contrived by Papin, and used in his digester and boilers, and has ever since constituted an essential appendage to every boiler. In its simplest form it is an obtuse conical valve, kept in its seat (which is at the end of a short collar, standing up from the surface of the boiler) by a weight acting at the end of a lever, resting on the spindle of the valve, and having its fulcrum or hinge at the other extremity. The effective weight by which the valve is kept down may be varied by shifting the position of the weight on the arm of the lever; and as this alteration might be unintentionally made by carelessness or accident, the valve should be inclosed in a box under lock and key, to prevent its being tampered with. A chain attached to the valve, and accessible to the engineer, should be provided, to enable him to raise the valve, to ascertain that it is in efficient order, and has not become fixed in its socket. But the best mode of applying the weight is directly on the valve, so that it cannot be increased, as long as it is inclosed, by any accidental alteration in its position. In locomotive engines the weight would be liable to derangement by the motion, and a spiral spring is employed to keep down the valve.

The safety-valve is perfectly effective as long as it is free to rise in its seat, and is loaded with a constant weight, which ought never to be more than one-third the pressure the boiler is just capable of withstanding. The rapid diminution in the number of accidents from explosions, notwithstanding the increased employment of steam, sufficiently proves that they are nine times out of ten caused by gross negligence or culpable recklessness; but to obviate as much as possible the recurrence of explosions, every boiler should have at least two safety-valves, both secured from access, and yet both capable of being raised by hand from time to time: one should be loaded with a less weight than the other, that by the escape of the steam from it the engineer may be warned to reduce the quantity of steam generated, by "damping" his draught; and the other safety-valve should be only loaded with a weight equivalent to one-third the pressure which, by computation founded on actual experiments, would burst the boiler, if made with metal of a given thickness; for, however carefully the boiler may have been made, it is impossible to ensure equal strength of it in every part.

A plan was originally suggested by Trevithick for insuring safety from a boiler by inserting in it a plug of metal, which, melting at the temperature attained by the steam when its tension became dangerous, might open an exit for it. This plan is adopted in France, but besides that it is repugnant to our ideas of mechanical fitness, it is liable to many objections; none of the pure metals melt at a temperature sufficiently low to be available, and all the fusible alloys soften long before they melt, and vary in these respects with minute differences in the proportion of their ingredients, so that the plug might be driven out before the proper time.

The boiler, besides the danger of bursting from over-pressure of the steam within it, is also liable to injury by the external pressure of the air, if the steam within be condensed, as it must be on cooling, when the fire is let out, thus causing a comparative vacuum in the boiler. To guard against this, there should be a safety-valve to act in the direction opposite to the usual one, which, yielding to the pressure of the atmosphere, would allow of the entrance of the air, when this pressure exceeded the one exerted by the steam to keep the valve closed.

Another source of accident, which should be guarded against most sedulously, is the formation in the boiler of a deposit of the earths, &c. chemically united with the water or held suspended in it, and which are deposited from all water when long kept boiling in any vessel, as is illustrated and proved by the furring of old tea-kettles. This deposit is intensely hard, and adheres so closely to the metal, that it requires a chisel and hammer to detach it when accumulated to any thickness. Being a bad conductor of heat, it prevents the rapid generation of steam, and by not allowing the water to be in contact with the metal, so as to carry off the heat imparted to the latter, the metal gets red-hot and is burnt, or, in chemical language, becomes oxidised by long exposure to a high temperature. If, under these circumstances, a fissure should be produced in the earthy crust, the water, suddenly admitted to contact with the red-hot iron, is converted instantaneously into steam of such high pressure as to risk the bursting of the boiler.

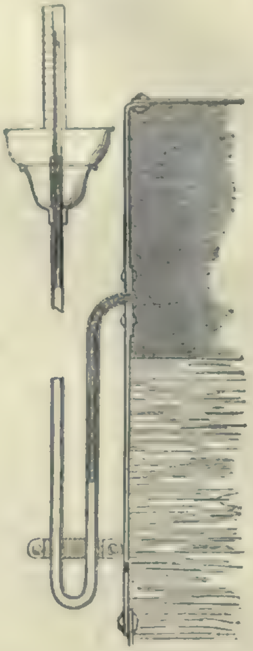
It is one of the advantages held out as an inducement to their adoption by the inventors of tubular boilers, that, owing to the inequality of the temperature of the liquid at different distances from the source of heat, a circulation is continually going on, which mechanically prevents the formation of a deposit, while in large open boilers no such cause can operate to any extent. In these the remedy appears to be the frequent cleaning out of the boiler, to prevent the accumulation of the deposit, and the admission of the water which supplies the waste to the part not over the furnace, which should be separated from the rest by a partition extending upwards nearly to the level of the water; the fresh water is thus allowed to deposit its sediment in the part where it can be least productive of the evils alluded to, and whence it may be removed collectively from time to time.

To indicate the actual pressure at any time of the steam within the boiler, this is furnished with a *gauge* (*fig.* 12), consisting of a bent tube, open at both ends, one orifice A opening into the boiler. This tube contains mercury, which will obviously be at the same level in both branches when the steam in the boiler is of the same pressure as the atmosphere, but will rise in the longer leg as the pressure of the steam increases, and will thus by its altitude indicate that pressure. If the longer leg be of a certain length, the mercury would flow over, or be blown out; altogether, if the steam were suddenly to increase in its elastic force, the gauge would in this case act as a safety-valve. The loss of the mercury may be guarded against, under these circumstances, by a cistern placed round the orifice of the gauge to receive it, as shown in the figure.

A water-gauge is often used instead of a mercurial one, to save the expense of this metal; but then the tube must be long enough to allow a sufficient column of water to balance the pressure of the steam; and by making the tube of sufficient diameter, this water-gauge then constitutes an efficient safety-valve. As these gauges cannot, for obvious reasons, be made of glass, to allow of the height of the fluid within them being directly observed, this height is indicated by a light wooden rod projecting beyond the end of the gauge, which floats on, and therefore rises and falls with, the mercury or water.

In locomotive-engines, where the use of a mercurial and still more of a water-gauge is impracticable, the same end is attained by a thermometer, on the well-known principle that the temperature of steam is always in a constant relation to its pressure; or by Bourdon's steam-gauge, in which the steam acts upon a diaphragm, as in the aneroid.

Fig. 12.



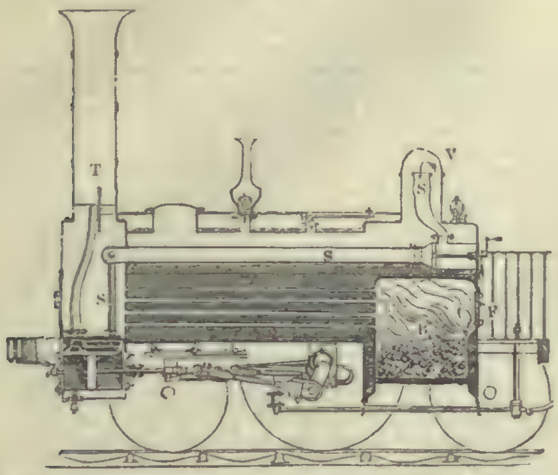
If there be not water in contact with that part of the boiler exposed externally to the direct action of the flame and hot air in the furnace and flues, the iron would become red-hot, and so suddenly increase the pressure of the steam in contact with it, that an explosion would probably ensue; and if not, the iron in that part would be more oxidised or burnt. To prevent this it is necessary that there should be always water in the boiler above the level of the highest part of the flues; and to enable the engineer to ascertain whether this is the case, there are in all boilers two pipes with cocks, one of which dips down into the water, while the other reaches only to within a few inches of its surface when at the right height in the boiler; the consequence of this arrangement is, that if the cock of the shorter pipe be opened steam will issue from it, and water from the other when that is opened in its turn; but if steam escapes from both cocks, the engineer is warned that there is not sufficient water in the boiler, and therefore directs his attention to remedy the deficiency.

The boiler is always supplied with water by the action of the engine; the hot water, pumped out of the condenser, is raised into a cistern placed at a sufficient height above the boiler, by the force-pump mentioned in the general description of Watt's engine; from this cistern a pipe passes through the top of the boiler, and reaches nearly to the bottom, where it is bent at right angles; the upper orifice in the cistern is closed by a valve connected by a spindle-rod with one end of a simple lever, from the end of the other arm of which a wire is suspended, supporting a stone float in the boiler, the valve being weighted just to counterbalance the specific gravity of the float; as the water subsides in the boiler in consequence of its evaporation, the float falls and raises the valve, allowing sufficient water to descend into the boiler till the float, rising again, causes the valve to close; the weight of the column of water in the pipe prevents the steam from escaping in that direction during the action of the valves; hence the necessity for the feeding-cistern being raised sufficiently above the boiler. The bend at the bottom of the feeding-pipe is intended to cause the water, when issuing near to the bottom of the boiler, to wash away the sediment which would otherwise collect there.

The locomotive-engine, as has been stated, requires a boiler of a form and principle totally different from those of an ordinary one.

The boiler A (*fig.* 13) is a cylinder made of wrought-iron plates, riveted together in the usual way, but it is covered with a wooden casing, to prevent, as far as possible, the great waste of heat which would radiate from a metal surface moving through the air with great velocity. At one end of the boiler is the furnace B, consisting of a double case, the outer one of iron with a semi-cylindrical head, but quite open at bottom; within this is an inner square case of sheet copper, riveted all round the bottom edge to the outer one, but leaving on its three sides a space of three inches between them, which is filled with water, and indeed forms a continuation of the boiler. The bottom of this inner case is the grating on which the fuel is laid. F is the feeding door in front, opening of course through both cases, which are therefore riveted together, so as to be steam-tight all round. A series of upwards of 100 brass tubes of small diameter pass from the back of the furnace to the further end of the boiler, where they open into the chimney. These tubes, which are entirely immersed in the water, constitute the flue, and thus increase considerably the heated surface in contact with the water, and therefore promote the rapid generation of steam. The introduction of these tubes forms an epoch in the construction of boilers, and was the suggestion of Mr. R. Stephenson, and simultaneously of M. Seguin, in 1829. [RAILWAY.]

Fig. 13.



The cylinders of the engine, of which one only can be seen in the section, are fixed at the bottom of the chimney. The steam passes to the slide-valve by the pipe S, S, while the waste steam escapes up the funnel at T. The cylindrical vessel with the spherical head V, is called the *steam-chest*, the steam-pipe terminating in it at S. The object of this arrangement is to prevent the water, which is agitated by the motion, from passing through the steam-pipe to the cylinder, where it would be highly detrimental; the main steam-pipe divides into two branches in the chimney, one passing to each cylinder.

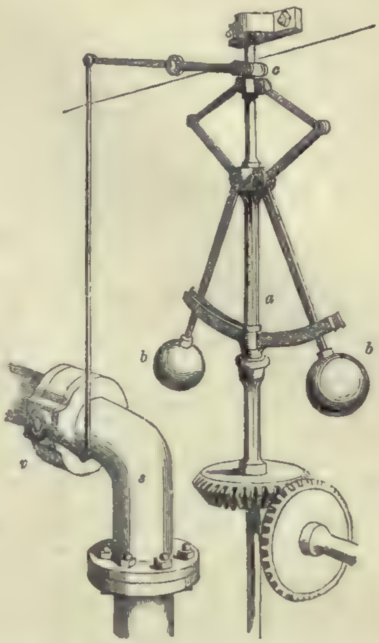
The boiler is supplied with water from the tender by two force-pumps worked by the engine, and has a gauge, try-pipes, safety-valves, &c., in common with other engines, though all peculiar in their construction.

This brief account of the boiler, and of its various arrangements, will hardly be considered complete without some notice of the explosions to which it is liable.

The bursting of boilers presents very different phenomena, being sometimes a simple rent in the metal, allowing the harmless escape of steam and water; and at others accompanied by an explosion in its violence equal to that produced by gunpowder; it has hence been conjectured that on these occasions some explosive gases are formed in the boiler; but this does not appear probable, nor is it reconcileable with any known physical laws, while the elastic force of steam is capable of indefinite increase, and is quite adequate to produce any mechanical effect whatever. It is always difficult to get any satisfactory evidence as to the facts of an explosion of a boiler; the terror of the moment prevents the survivors from accurately recalling the phenomena immediately antecedent, while those who from their proximity would be best capable of affording this evidence, are either killed, or are too interested in exculpating themselves to be impartial witnesses. With regard to the formation of explosive gaseous compounds in the boiler, it is generally admitted that hydrogen gas is the only ingredient of such that can be formed; and that is obtained by the decomposition of the steam when in contact with the red-hot iron; but pure hydrogen is not explosive; and to render it so it must be mixed with oxygen or atmospheric air. It has been suggested that the latter may be introduced along with the water by a defect in the feeding-pump; but the proportions of the air and of the hydrogen must be definite to produce an explosion; and it is difficult to suppose that in such a situation either should continue to accumulate till the quantity is exactly that necessary to produce an explosion. In short this explanation of the subject is beset with difficulties which have not yet been removed, though the attention of scientific men both in Europe and America has been frequently directed to it.

Whenever the steam-engine is employed to execute any work which is variable in its quantity or intensity, there must be some means of adjusting the force of the engine to this varying resistance it has to overcome: if the engine were suddenly relieved of half that resistance, as, for example, would be the case if half the machinery it was driving were suddenly stopped or thrown out of gear, the engine, if impelled by the same quantity of steam, would immediately move with a rapidly accelerating velocity, till that velocity were doubled, which would be prejudicial to the engine itself and to the rest of the machinery it was working, as well as be a useless expenditure of force or fuel. The object of that beautiful piece of mechanism termed the *governor*, is to enable the engine to regulate the supply of steam admitted to the cylinder, or in other words to adapt the force it has to transmit to the resistance it has to overcome.

Fig. 14.



The governor, the form and principle of which will be better understood from the figure (*fig.* 14) than from any description, is made to revolve on its vertical axis *a*, by a band passing round a pulley and round one on the axle of the fly-wheel, or else by bevilled wheels, as shown in the figure; so that its velocity of rotation varies with that of the fly-wheel. If this velocity increase, the heavy balls *b b* diverge by the increased centrifugal force, and cause the collar *c* to slide up the axis; this by means of the intermediate cranks partially closes the valve at *v*, in the steam-pipe *s*, termed the *throttle-valve*, and consequently diminishes the quantity of steam passing to the cylinder: if, on the contrary, the velocity of the fly-wheel is diminished by an increase in the resistance, the balls of the governor collapse, and the throttle-valve is opened so as to admit more steam to the cylinder to augment the force in proportion to the increased resistance.

The effect on the governor is equivalent to varying the diameter of a second fly-wheel, the circumference of which is represented by the balls *b b*, consequently the governor itself, independently of its action on the throttle-valve, has a tendency to effect the adjustment required; since a portion of the surplus force of the engine, on the first supposition, is absorbed in overcoming the increased inertia of the governor; while, on the second supposition, that inertia, being diminished, relieves the engine of a portion of resistance. This accounts for the prompt action of the governor in effecting the adjustment, which it does without those fluctuations in the velocity of the piston which would be prejudicial to the effect of the machinery actuated by this prime-mover.

In the marine engine no governor is requisite; the resistance being so great compared to the force, that the velocity can never be excessive, and all the power the engine is capable of exerting is required to turn the paddle-wheels; added to which the resistance is nearly uniform, only varying with the draught of the vessel or the state of the weather, but never diminishing below that originally calculated on and provided for by the power of the engines; an increase of the resistance accordingly produces a diminution in the velocity of the vessel, but the engine can never work so fast as to be injured by its own velocity.

The governor is equally unnecessary to the locomotive engine, since the attendant must constantly have the engine under his control, and be watching its action; he can therefore regulate the throttle-valve by hand-gear placed within his reach; and in this case also, as with the marine engine, the resistance is nearly constant, consisting chiefly in the weight of the engine and the train of carriages to be moved, a weight not liable to any sudden change during the transit, while the momentum of the whole mass acts as a fly-wheel or regulator to equalise the motion of the pistons.

We have not entered into any investigations of the formulæ for determining the dimensions of an engine and of its boiler, the pressure at which it must be worked, the velocity of the piston, &c., in order to produce any proposed available or net force; or into the account of the experiments by which the amount of friction, the effects of the uncondensed steam, the quantity of caloric obtained from different kinds of fuel, &c., all of which must be taken into account in these investigations, and have been approximatively determined.

(In the preceding article the formulæ expressing the physical and mechanical properties of steam will be found, and for the others the following works among others may be consulted: Tredgold, T., *On the Steam-Engine;* Farey, J., *On the Steam-Engine*, 4to.; De Pambour, F.M.E., Chev., *Théorie de la Machine à Vapeur*, 8vo., Paris; Galloway, *On the Steam-Engine*, and others.)

STEAM-CARRIAGES on common roads have for many years occupied the attention of engineers and mechanicians, on account of the evident economy which would result from the use of a road surface adapted to, and previously constructed for, ordinary traffic; but, up to the present time, none of the systems which have been proposed for the construction of these engines can be considered to have entirely overcome the practical difficulties attending the transport of the weights required in the machinery and boilers, or the variable resistances encountered. Some of the more recently introduced traction engines seem, however, to contain, in germ, the elements of the successful solution of the problem of steam locomotion, by engines of small power, running on roads possessing an inferior degree of theoretical perfection than well maintained railways; and the introduction of the street railways certainly justifies the belief that, ere long, steam-engines may be used upon them between points which would not require, or justify, the construction of regular railroads. A short notice of the most celebrated attempts to adapt steam-carriages to common roads may, therefore, be desirable, accompanied by a few remarks on the characteristic distinctions between the resistances to be overcome in the respective cases of rail, or of common, roads.

When steam-carriages work upon railroads, they traverse a surface of uniform hardness and rigidity; and it is easy to distribute the load over a number of carriages drawn by the engine, because the rails maintain the various parts of the train in the desired positions with respect to one another. No difficulty either occurs, in this case, on the score of the guidance of the engine or of the load; nor is it necessary to provide for avoiding obstacles in the road, or on account of sharp curves or bends. On common roads, however, the yielding nature of the surface imposes a limit to the weight brought upon the driving-wheels; and the state of the surface as affected by wet, by the addition of fresh metal, or by other accidental causes, must materially increase the irregularity of the resistance. The rates of inclination adopted on common roads, and the small radii of curvature frequently met with upon them, are far more unfavourable than those met with in railways; and it is found in practice that there are serious objections to the use of more than two carriages in immediate connection with one another on common roads; so that forcedly the space devoted to the reception of the machinery, boiler, combustible, &c., is confined within very narrow limits, in order to leave any space available for the conveyance of passengers or of goods. The irregularity of resistance of the road surface renders it necessary also to adopt great precautions in the construction of the parts of the engine designed to transmit motion from the piston-head; and the constant changes of inclination require that there should be provided, in steam-carriages designed to run on common roads, means for varying at will the amount of power exercised. In all locomotives it is desirable that the machinery should be of the simplest construction, and that it should be susceptible of easy examination and repair; but this is essentially the case with steam-carriages, on account of the variety of action required of them. The consequences of these peculiar conditions are that steam-carriages must be made to combine great power within small compass, and with small dead weights; they must be constructed so solidly as not to be deranged by the shocks, or the bad state of the roadway; and lastly, they must be able to work without producing any nuisance, or any interference with the ordinary horse traffic of the public thoroughfares. Hitherto it has not been found possible to secure these conditions, and to secure economy of traction at the same time; and the substitution of steam for animal power is still confined to railways, notwithstanding the enormous amount of capital they require to be expended on their construction.

It appears that as far back as 1786 attempts were made by William Symington, in Scotland, and Oliver Evans, in Philadelphia, to introduce steam carriages, or waggons, on common roads; and Mr. Murdoch, the well-known associate of Boulton and Watt, is said in 1782, or 1792, to have made a similar attempt. In 1802, Trevethick and Vivian produced an engine for the same purpose of much greater value than those previously made. After their trial, some years elapsed before other parties took up the question, and it was not until 1821 that Griffith patented his steam-carriage. In 1822 David Gordon began his public essays on the subject, and in the succeeding years he took out several patents connected with it. He was, in 1824, followed by many other inventors, such as Hancock, Summers and Ogle, Dr. Church, Sir J. Anderson, Sir C. Dance, Mr. J. Scott Russell, &c. The success of these experiments was, as might have been expected, of a varied character; but they seem to have roused a singular amount of local opposition, which finally assumed so violent a character as to lead to the nomination of a select committee of the House of Commons to inquire into the "present state and future prospects of land carriage by means of wheeled vehicles propelled by steam or gas on common roads." The report of this committee was published in October 1831. Although this report was favourable to the new application of steam-power, and although Mr. Hancock in 1831 produced a steam-carriage which, like the one proposed about the same time by Mr. Goldsworthy Gurney, answered to a great extent the anticipations of their inventors, the difficulties attending this mode of locomotion were considered to be so great, that about 1832 the conviction in the minds of practical engineers had become almost universal that "every attempt then made to render steam-carriages the means of economical and regular inland communication had totally and absolutely failed." The success of the railway system, then first applied on a large scale, served likewise to turn public attention from the avowedly inferior system of steam locomotion on common roads; and it was not until the recent application of steam-machinery to agricultural purposes had rendered it desirable to introduce some mechanical traction-engines of great power, that engineers were again induced to study this particular problem. In the Great Exhibition for 1851 there was only one plan of a locomotive for common roads; but between 1858 and the end of 1860 as many as nine varieties of those engines were submitted to the public, of sufficient importance to merit the attention of the professional journals and occasionally of the various departments of the government. Of these, Boydell's, Clayton's, Burrell's, Bray's, Giles's, and Stirling's traction-engines, Lord Caithness's steam-carriage, Aveling's self-propelling agricultural engines, and the engine made by Mr. Creswell for the English and Continental Traction-Engine Company, have attracted the greatest amount of notice, and some of them have actually performed good work. Bray's traction-engine, for instance, has been usefully employed in our dockyards. Lord Caithness reports that with his carriage, having cylinders of 3 inches diameter and 7 inches stroke, he was able to attain on the level a speed of 19 miles an hour, and to ascend inclines of 1 in 7, working at an average expense of from a halfpenny to a penny per mile; the weight, with water for a run of 12 miles, and coals for 20 miles, is only two tons; but the carriage only conveys (in the form represented in the 'Engineer' for Oct. 19, 1860) three passengers. Creswell's engine is said on one occasion to have drawn two waggons containing 10 tons of earth each up Pentonville Hill, a long incline of about 1 in 70; but on a repetition of the experiment it broke down. There seems, therefore, to be some reason for the belief so confidently expressed by Lord Caithness, that ere long steam may be substituted for horse-power on common roads; and as the prejudice against its use has, since 1831, been considerably diminished, the most bitter source of opposition has disappeared. The application of the expansion gear, and the introduction of street railways, must however be considered to have effected the greatest service towards the introduction of steam locomotion without the construction of special roadways. With all their modern improvements, steam-carriages are nevertheless still but imperfect substitutes for railway travelling, and it may almost be a subject for regret to witness the amount of energy, skill, and money expended upon them.

The best information on the construction of steam-carriages is to be found in Gordon's 'Treatise upon Elemental Motion;' Hancock's 'Narrative;' the 'Mechanics' Magazine;' the 'Engineer;' and the Reports of the Select Committees of the House of Commons in 1831, and 1834 and 1835, upon Steam-Carriages and upon Goldsworthy Gurney's claims.

STEAM NAVIGATION. It would seem that navigation, being founded on the bases of geometry and astronomy, would be but one system, practicable alike by the commander of a sailing ship or of a steamer; that practice attained in navigating one class of vessels would be equally available for the safety of the other; but it is not so. As well may we compare the driving of a spirited horse in a light gig to the driving of a waggon team: there are points of skill in each, and proficiency is also attainable in each, but interchange the drivers, and it is probable that neither of the vehicles would be so well conducted as before:—and thus it is with steam navigation. The sailor of the old school (for there is specifically a *new* one), is accustomed to have his eyes aloft; and the trim of his sails, and the steadying of a bowline here, and the pulling upon a brace there; the habitual look to windward for coming weather, &c.; these form the main sources of that unceasing vigilance without which no one can be fit to command.

The navigation of a ship (in its abstract meaning), is with the sailing commander a mere routine. A course of measured attentions to certain established customs, handed down from generation to generation, and performed at definite periods, leaves his mind, after those periods have passed, nearly free from the duties of calculation altogether. But in the new school, things are far different, and it will be useful in this place to illustrate the present state of the subject, by examining into what really constitutes this difference, for it becomes a question of training and qualification.

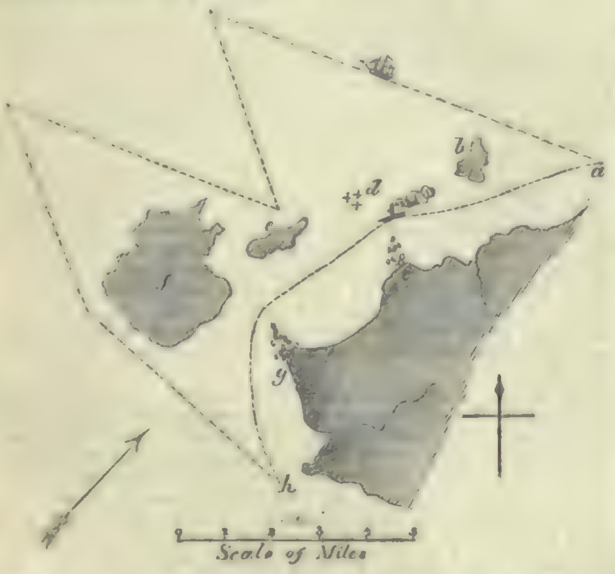
We have only to refer to our article Collisions at Sea, to show that fearful innovations have followed the introduction of steam into our sea services—affecting in a high degree the safety of life; and we also refer to Ships and Shipping to show what laws are found necessary in preventing such insecurity. Fearful then must be the increased responsibilities of a commander of a steam vessel. Nor does this admit of limitation, for the very causes of all this are in themselves progressive.

Very much may be attributed to the increase of speed in steamers; yet there are other influences which affect steam navigation with peculiar force: among these may be noticed the wide prevailing interest that owners, of steamers in particular, feel in the rapidity of their voyages. Hence, every advantage which can be taken to accomplish this, is considered part of a commander's duty—and his position, therefore, depends much upon his habitually making a quick passage.

The following will explain the work of each kind of navigator. In the sailing ship, the master daily at 1 bell in the forenoon watch (half-past 8 a.m.) takes his sextant upon deck to obtain an altitude of the sun, in readiness for working his time at ship: he defers this work till noon, at which he will have obtained his ship's latitude from a meridian altitude. During the forenoon, or from nine o'clock, his only work connected with navigation-proper, is an occasional glance over the side of the ship, in order to estimate the ship's "way" (velocity), and also at times at the binnacle compass to get an opinion as to the accuracy of the course about to be marked on the log-board. [Dead-Reckoning.] The ship's position at noon having been pricked off upon a chart, and the log duly written up as soon after noon as convenient, the remainder of the day calls for no further computations,—unless, as it occasionally happens, sights for the time were not procurable in the forenoon, and are taken at about 3 p.m, it being better to obtain them when the sun is about three hours from the meridian. Occasionally, a sailing navigator may see fit to try a lunar for his longitude, but this is entirely optional; or, perchance, in the evening an intelligent merchant captain may desire to verify his position by observation of a star, &c. So then as regards routine observation, the work of a sailing commander is very light. For even, if in addition to his daily routine he be approaching land, it entails no serious loss or labour to "lie-to" for a few hours till daylight.

But with a commander of a steamer, navigation is quite another thing; for in the first place, where a sailing commander deems it advisable not to close in with the land towards nightfall, because he depends upon the wind only, a change in which might suddenly place him on a lee shore; the steam commander would, as a matter of duty, take the shortest route, in whatever direction that might lie. It will then be evident that with a vessel of greater comparative speed, often using the more dangerous passage along a coast, her commander should be a man of increased nautical skill, and of special proficiency in navigation—the latter attainment being the more needed as he has scarcely the discretionary power to "lay-to," except under special circumstances. The stranding of a sailing ship may often be the result of sheer accident of wind or weather, while that of a steamer, which is locomotive, and can steer readily in any direction (in moderate weather), has been in too many instances found to have its cause in at least error in judgment.

To make the distinction between steam navigation and sailing navigation the plainer, we will suppose a case, as applicable to the following imaginary chart and track:—



Two vessels, the one sailing and the other steaming, are bound round the headland, *g*, of a continent. There are several outlying dangers near it, such as the island *b*, the rocks at *d*, the shoal at *e*, and in addition, rocky spits run off the points *c* and *g*. Suppose the two vessels to be in company at *a*, and each desirous of reaching the position *h*: the steamer would, as a matter of course, take the inner passage, in whatever direction the wind might blow, while if the wind were as indicated by the arrow in the diagram, the sailing ship could not venture, but must take the outer passage—and as a square-rigged ship can only sail within about six points of the wind, her track in working to windward or "tacking," would in this case between *a* and *h* be about thirty miles, while the steamer's would be about twelve. Now if we compare the two tracks it will be evident that the mind of the sailing master might well be free from care, except when approaching *e*, or the weather side of *f*; while during the whole passage, through a slight mistake or inattention on the part of the steam commander, he might lose the ship. Suppose farther, that just as the steamer reached her position near *d*, the weather became hazy or foggy, obscuring the land: the master of the sailing ship in the offing could without a care lay-to with the ship's head off the land, while the steamer must push on, if possible; because anchoring would inconveniently delay her passage. He would have in such case to prick off his actual position on his chart by hasty bearings, subject to the delay of correction for local attraction, &c., and indeed his work of navigation would form a perfect contrast to that of the ship-master outside. Farther investigation will even heighten the contrast, for in a passenger steamer, the commander finds the necessity of verifying his position as often as possible, by night as well as by day. He takes a larger number of observations, and needs every accomplishment which nautical astronomy offers him.

If then such disparity exist in the duties of certain maritime commanders, and if, moreover, no amended system of training have been yet perfected under authority, calculated to meet the increased intelligence called for by the exigence of steam navigation, the subject is worthy of most earnest attention.

An impression is gaining ground among experienced commanders themselves, that whereas other professions have their training based upon principles which are carefully explained to them, the navigator is consigned to work with formulæ of which he has no comprehension beyond their mere adaptation to his work. Trigonometry, plane and spherical, is the foundation of all his calculations, but neither are its principles explained in schools of navigation generally, nor is even the projection of its figures deemed important. In the Royal Naval School, and one or two others, this great defect has been of late attended to, and their example cannot, for the good of the community, be too soon followed by those who have had the training of nearly 50,000 of our population whose profession is that of the sea officer. That our sea captains are successful in their voyages as a general rule, depends on their perseverance and intelligence as a body: they complain that they owe little to science and teaching.

With regard to spheric trigonometry, circumstances already explained under Great-Circle-Sailing have strangely driven it from even the "Manual" of the Navigator. [Spherics; Spherograph.]

(Raper's *Treatise on Navigation*; Jean's Works on Trigonometry; *The Calculation and Projection of the Sphere*, Longman & Co.)

STEAM-VESSEL, a vessel moved by the power of a steam-engine acting upon paddle-wheels or other mechanism for propelling it through the water. Under Ship, Ship-building, &c., were explained the principles on which vessels are constructed; and under Steam, Steam-Engine, Propeller, &c., have been described the means of propulsion. Before entering upon the construction of steam-vessels, we give a brief notice of the rise and progress of the application of steam to navigation.

A curious claim has been brought forward on behalf of Blasco de Garay, a sea captain, who is stated to have exhibited in Spain, in 1543, an engine by which ships and vessels of the largest size could be propelled, even in a calm, without the aid of oars or sails. The documents relating to this claim, which, if correct, gives Spain the priority by a long period in experiments on steam navigation, were discovered in the royal archives at Simancas, and were published in 1826, by Thomas Gonzales, director of the archives.

Stuart, in his 'Anecdotes of Steam-Engines,' endeavours to establish something like a claim to the invention of steam navigation by the Marquess of Worcester. The author alludes to a little engine, or great model, which he had "already erected" at Lambeth; and among many other purposes to which his invention might be applied, states that it may be used "to draw or hale ships, boates, &c. up rivers against the streame; to draw carts, wagons, &c. as fast without cattel; to draw the plough without cattel, to the same despatch if need be," &c.

The project to be next alluded to is that of Papin, who proposed an apparatus somewhat like that subsequently patented in England by Jonathan Hulls. Those who have endeavoured to establish a claim to the invention of steam navigation on behalf of France, have pleaded Papin's suggestion in favour of their views; but none, so far as we know, have asserted that he put his scheme to the test of experiment.

On December 21, 1736, a patent was granted to Jonathan Hulls for a machine which may be designated a steam tug-boat; of which a full description was published in the following year, in a sensible pamphlet, entitled 'A Description and Draught of a new-invented Machine for carrying Vessels or Ships out of or into any Harbour, Port, or River, against Wind and Tide, or in a Calm.' Hulls proposed to place an atmospheric steam-engine in the tug-boat, and to communicate its power by means of ropes to the axis of a kind of paddle-wheel mounted in a frame-work projecting from the stern of the vessel. A contrivance is added for continuing the motion of the paddles by the descent of a counterbalance-weight, in the intervals between the strokes of the piston. To guard against the injury of the fans or paddles by the violence of the waves, Hulls proposed to lay pieces of timber so as to swim on each side of them. The objections likely to be brought against the scheme are anticipated and answered by the writer, who expresses his opinion that it would be found better to place the machine in a separate vessel than in the ship itself, because the machinery would be cumbersome in the ship, and, if in a separate vessel, it might lie at any port to be ready for use, &c.

The next circumstances which claim notice in the history of the invention of steam navigation afford the principal reasons for attributing, as some of their writers have done, the origin of the art to the French. In 1774, the Comte d'Auxiron, a French nobleman of scientific attainments, constructed a steam-boat, and tried it on the Seine, near Paris. It appears that the engine had not sufficient power to move the wheels efficiently, an error into which many of the early experimenters fell; and consequently the result was unsatisfactory, and the persons who had united to enable the Comte to construct the machine, abandoned the project. In the next year, 1775, the eldest of the ingenious brothers Perier, who had assisted in d'Auxiron's experiment, resumed the attempt, and placed a very imperfect engine, of about one-horse power, in a boat on the Seine, connecting the engine with two paddle-wheels. He also laboured under the disadvantage of having too little engine-power, and therefore failed to obtain any satisfactory result; his boat moving but slowly against the current of the Seine. Fortified by the favourable opinion of the Marquis Ducrest, who perceived the cause of his disappointment, "Perier did not," observes Stuart, "altogether abandon the subject; and in succeeding years he made a few attempts with other propelling mechanism instead of paddle wheels, which he thought were defective substitutes for oars, and which, in his view, occasioned his failure." He did not, however, accomplish anything important; nor did his attempts, according to the author just quoted, excite much attention in France, or any at all in England. In an Historical Notice on Steam-Engines, by M. Arago, in the French 'Annuaire' for 1837, it is stated, probably from inadvertence, that M. Perier was the *first* to actually construct a steam-vessel. From this paper we learn that trials were made on a larger scale, in 1778, at Baume-les-Dames, by the Marquis de Jouffroy, who, in 1781 or 1782, tried a boat of considerable dimensions upon the Saône, at Lyon. Several English authorities give the dimensions of this boat as 140 feet long and 15 feet broad; but Arago says it was 46 metres long and 4½ broad. Colden's 'Life of Fulton,' in an extract from the 'Journal des Débats' for March 28, 1816, states the dimensions to have been 130 feet long and 14 broad. The vessel had a single paddle-wheel on each side, and the machinery appears to have been constructed with some skill, although it was not sufficiently strong. The experiments of the Marquis were eventually stopped by the political disturbances of the country. After a long exile, he returned to his country about 1796, and found that M. des Blancs, a watchmaker of Trevoux, had obtained a patent for a steam-vessel, which, it has been supposed, was constructed chiefly on the information which he could collect respecting that of the Marquis. Jouffroy appealed to the government, but nothing important resulted from his doing so, or from the experiments of M. des Blancs, which, like those of Jouffroy, were made on the Saône. While M. des Blancs was engaged in his steam-boat project, Fulton, who was then in France, was also experimenting upon the same subject. It appears, indeed, that both tried the scheme of propelling by means of paddles or float-boards attached to an endless chain stretched over two wheels projecting from each side of the vessel. Fulton abandoned this plan, and adopted paddle-wheels in its stead; but during his experiments, M. des Blancs complained of his operations as an infringement upon his patent right, and remonstrated with Fulton upon the subject.

The narrative must now return a few years, in order to notice the attempts making in North America to solve the problem of propelling vessels by mechanical power. Without noticing mere vague suggestions of its possibility, of which some have been mentioned of earlier date, we find that two individuals named Fitch and Rumsey were early in the field as experimentalists. Stuart goes into their claims very minutely; but it may be briefly stated that as early as 1783 Fitch had succeeded in moving a boat on the Delaware by means of paddles (not paddle-wheels) set in motion by a steam-engine; and that in 1785 he presented a model and description of his apparatus to Congress. He was supported for some time by an association of wealthy persons, and was so sanguine as to the success of his project, as to send drawings and descriptions of his machinery to Messrs. Boulton and Watt, in order that they might procure an English patent for it. Nothing was accomplished by Fitch and his friends in England, and but little in America. It is worthy of notice that Fitch expressed his belief that the time would come when steam-power would be employed for crossing the Atlantic. Rumsey, the rival of Fitch, had exhibited a model of a contrivance for moving a boat, to General Washington, as early as 1784; but Fitch alleged that it was merely an apparatus for enabling a boat to stem the current of rapid rivers, by means of wheels, cranks, and poles; and that it had been tried some years before by another person on the Schuylkill, and had failed. In 1787, Rumsey made some short voyages on the Potomac, with a boat about fifty feet long, propelled by the re-action of a stream of water drawn in at the bow and forced out at the stern by means of a pump worked by a steam-engine. This boat moved, it is said, at the rate of three or four miles an hour, when loaded with three tons, in addition to the weight of her engine, which was about one-third of a ton. The boiler held only five gallons of water, and the whole machinery did not occupy more space than four barrels of flour. The fuel consumed was from four to six bushels of coals in twelve hours. Rumsey afterwards proposed applying the power of a steam-engine to long poles, which were to force the boat forward by reaching the bed of the river, when it had to move against a rapid current. Rumsey, as well as Fitch, was backed by a company; and their respective friends did not confine their rivalry to America, for the adherents of Rumsey addressed themselves to Boulton and Watt in opposition to the statements of Fitch. After all their conflicting pretensions, however, neither succeeded in the practical establishment of steam navigation. Rumsey came to England after the failure of his projects in America, and commenced a steam-boat on the same principle as that he had used on the Potomac, which was in some respects like the much older plan (1730) of Dr. John Allen. He died before the completion of this vessel; but it was finished by the persons associated with him, and was brought to trial in February, 1793. This steam-boat performed several times on the Thames, against wind and tide, and attained a speed of four miles an hour. This method of propelling a boat was subsequently tried by Mr. William Linaker, master-shipwright in Portsmouth dockyard, who obtained a patent for it in 1808. His experiments had, as appears by his papers, been commenced as early as 1793. Stuart states that a similar apparatus was tried on the Thames after Linaker's death, the engine used being on the principle of that invented by Savery.

While Fitch and Rumsey were making their experiments in America, other experiments were in progress in Scotland, which tended, more than any previous trials, to the useful application of steam to the purpose of propelling vessels. Of the highly interesting experiments made in 1788 and 1789, under the auspices of Patrick Miller, Esq., of Dalswinton, in Dumfriesshire, many accounts are extant, differing indeed very slightly from each other, yet tending, by the colouring given to minor details, to attribute different degrees of honour to the three individuals by whom they were carried out. It is not likely that this question will ever be thoroughly set at rest; for the degree in which each contributed to the success of the experiments will ever be estimated differently, according to the peculiar mode of judgment adopted by the inquirer. Without desiring to throw any slight upon those who differ from him, rather in his deductions than in the facts upon which they are based, our narrative will be condensed from that of Mr. Russell, who has evidently taken much pains to produce a satisfactory account of the whole course of proceedings.

After stating that it has been very usual to attribute the invention of steam navigation to Miller, and that two competitors have contested his claim, Mr. Russell observes, "We shall soon see that to no one of the three can the palm be awarded. The creation of the steam-ship appears to have been an achievement too gigantic for any single man. It was produced by one of those happy combinations in which individuals are but tools working out each his part in a great system, of the whole of which no single one may have comprehended all the workings." The persons who have contested the title of inventors of steam navigation, or rather, they for whom the title has been contested by others, are Patrick Miller, James Taylor, and William Symington; and, after a long and patient examination of their respective claims, and of the papers, published and unpublished, of the parties who advocate the cause of each, as well as of the personal testimony of such individuals as could throw light on the case, our author gives it as his conclusion that the art of steam navigation was the joint invention of the three. It will be seen from the history given above, that if the mere suggestion of applying a steam-engine to the propulsion of a vessel, or even the actual construction of a steam-boat, be considered sufficient to entitle a person to the name of inventor of steam navigation, that name belongs to some earlier projector, Hulls for instance, and not to any of the three individuals just mentioned; and if, on the other hand, the honour be due to those who produced the first successful steam-boat, it cannot be applied with propriety to any individual, seeing that the superiority of the boats of Miller, Taylor, and Symington was attributable to a happy union of talent and enterprise.

Mr. Miller, of Dalswinton, had been engaged in attempts for the improvement of naval architecture, proposing to build ships of much greater length than usual, in proportion to their breadth, and, in order to enable such narrow vessels to bear sail, to unite two or even three boats or hulls, side by side, so as to form a double or triple boat. He had also experimented upon the application of paddle-wheels, turned by a power within the vessel, instead of, or rather as auxiliary to, the force of the wind. Russell observes, that he does not find that Miller anywhere claimed absolute property in the invention of paddle-wheels, which, as has been already stated, had been often tried. Having thus prepared a form of vessel suitable for the purpose of steam navigation, and provided it with an apparatus for propelling it through the water, it only remained to apply the steam-engine itself. This, it appears, was done subsequently, in consequence of the suggestion of Mr. Taylor, who, in 1785, went to reside in Mr. Miller's family as tutor to his younger sons, and, in 1786 and 1787, frequently assisted in his experiments with paddle-wheel boats. In one of these, in the latter year, one of Miller's double boats, sixty feet long, propelled by two wheels, each of which was turned by two men, was matched against a Custom-house boat, which was reckoned a fast sailer; and on this occasion the want of a sufficient moving power to turn the wheels was sensibly felt. Both Miller and Taylor perceived this; but when the latter suggested the steam-engine, Mr. Miller, for a time, questioned its applicability. In 1787 he published an account of his experiments, in which he observed, after describing his paddle-wheels, "I have also reason to believe that the power of the steam-engine may be applied to work the wheels, so as to give them a quicker motion, and consequently to increase that of the ship. In the course of this summer I intend to make the experiment; and the result, if favourable, shall be communicated to the public." This project formed the subject of much conversation at Dalswinton in the summer of 1787, and was mentioned by Taylor to his intimate friend Symington, who was then engaged as a mining-engineer at the Wanlockhead lead-mines, but had devoted much attention to the improvement of the steam-engine, and had recently constructed a model of a steam-carriage [STEAM-CARRIAGES], in which he had provided simple means for converting the reciprocating motion of the pistons into a rotatory motion. Thus, while Miller had been preparing a proper vessel and propelling apparatus, and Taylor had been recommending the agent required to work it, Symington had been effecting those modifications in the structure of the engine which were necessary to adapt it to the purpose required. There is some reason, indeed, to believe that he had conceived the possibility of this particular application of the steam-engine; for, in a letter to Taylor, dated August 20, 1787, apparently in answer to one just received from him, Symington says, "I must make some remarks upon your summer's inventions, which, if once made to perform what their author gives them out for, will undoubtedly be one of the greatest wonders hitherto presented to the world, besides its being of considerable emolument to the projector. Great success to you, *although overturning my schemes*." In December of the same year the Dalswinton experimenters were in Edinburgh, where they met Symington, and, at the house of his patron, Gilbert Meason, Esq., saw his steam-carriage model. The result of this meeting was, that Symington, in conjunction with Miller and Taylor, constructed a small engine in the following summer; the castings being, by a curious coincidence, executed by a founder of the name of Watt. In October, 1788, this engine was placed in a small double pleasure-boat belonging to Mr. Miller, and was tried upon Dalswinton lake. The engine was placed on one side, the boiler on the other, and the paddle-wheel in the middle. With all the disadvantages of a first experiment, and with cylinders of only four inches diameter, the boat moved with a velocity of five miles an hour. After repeated satisfactory trials, the engine was removed from the boat, and kept for many years as a trophy in the library at Mr. Miller's.

Had the experiments of Miller and his fellow-labourers stopped here, it might have been conceived that their success was in some degree attributable to accidental circumstances. The result of a second experiment, in the following year, is sufficient to dispel any such idea. In 1789 an engine of about twelve-horse power (or twelve times the power of the first) was made by the same parties at the Carron works. This was mounted in the large double boat which had formerly run against the Custom-house boat at Leith. Except in size, this machine resembled the former model. The engine was commenced in June, and near the end of the year the boat was tried on the Forth and Clyde canal. Some difficulty was at first experienced from the weakness of the fastenings by which the float-boards or paddles were secured to the arms of the paddle-wheels; several of them being broken off by the severe strain to which the power of the engine subjected them. When this matter was set right, the boat performed very successfully, and attained a speed of nearly seven miles an hour, "being," observes Mr. Russell, "about as great a velocity as it has been found possible to obtain by steam-boats on canals, even at the present day." The vessel having been built for a different purpose, and being much too slight for permanent use as a steam-boat, or for taking out to sea, was, soon after the trial, dismantled. Mr. Miller, having thoroughly proved the practicability of the plan, and having expended a large fortune in his enlightened pursuits for the public benefit, relinquished the experiment, leaving its great results to be worked out by others. That he should have done so need excite no surprise, when the difficulties attending the introduction of any great improvement are considered. Taylor was still less likely to take any effective steps for carrying out the grand design; and Symington was not in a situation to do so immediately, although he was subsequently engaged in further experiments to that end.

Satisfactory as was the result of these experiments, they did not immediately lead to the introduction of steam navigation; and several other unsuccessful schemes were tried in this country and in North America before it was effected. One of these, that of Rumsey, the American, on the Thames, has been already mentioned. About this time Dr. Cartwright contrived a steam-barge, and explained it to Fulton. Some authorities state that it was shown to Fulton in 1793, when he was studying painting under West; but others date it a few years later, stating that he was introduced to Dr. Cartwright during his journey to Paris in 1796. However this might be, it is evident that Fulton's attention was directed to the subject about this time. Colden, his biographer, states that he made drawings of an apparatus for steam-navigation in 1793, and soon afterwards submitted them to Lord Stanhope. In 1795, Earl Stanhope himself made experiments with a steam-vessel propelled by duck-feet paddles placed under the quarters, like those recommended in 1759 by Genevois, a Swiss pastor. Notwithstanding the ingenious folding of the paddles, in order to diminish the resistance of the back-stroke, the apparatus required so much power that, with a powerful engine, he could not obtain a speed greater than three miles an hour.

In 1801 Symington commenced a satisfactory series of costly experiments on steam-navigation, under the auspices of Thomas, Lord Dundas. The object immediately aimed at was the introduction of tug-boats instead of horses for drawing boats upon canals. After several minor trials, one of the boats built on this occasion by Symington drew, on the Forth and Clyde canal, in 1802, two loaded vessels, each of seventy tons burden. On this occasion, it travelled with its load a distance of nineteen miles and a half in six hours, although there was so strong a wind ahead that no other vessels in the canal could move to windward on that day. The tug-boat was a rather short vessel, with a single paddle-wheel in the stern, impelled by a horizontal cylinder of twenty-two inches diameter and four feet stroke, working, by means of a connecting-rod, a crank on the axle of the wheel. The rudder was double, on account of the situation of the paddle-wheel, and it was moved by means of a tiller-wheel in the fore-part of the vessel. A complete model of this boat may be seen at the Royal Institution of London. In this case, though the object aimed at was fully attained, as far as the successful performance of the vessel could go, the project was abandoned, in consequence of an idea that the undulation of the water occasioned by the paddle-wheel would prove injurious to the banks of the canal. The speed attained by this steam-boat, when unimpeded by having any others to draw after it, was about six miles an hour.

While the experiments of Symington, under the patronage of Lord Dundas, did not lead to the immediate adoption of steam-vessels for commercial purposes, they probably tended, in no unimportant degree, to their subsequent profitable establishment in America and in Great Britain; for among the numerous individuals who inspected his vessel with interest were Fulton and Bell. It has been shown that projects for steam-navigation had been early tried in North America. After Fitch and Rumsey, the chancellor Livingstone attempted to build a steam-boat on the Hudson, and in 1797 he applied to the legislature of the State of New York for an exclusive privilege to navigate boats by a steam-engine. Though his project excited much ridicule, the privilege was granted in 1798, on condition that he should, within twelve months, produce a steam-vessel which should attain a mean rate of at least four miles an hour. This he failed to accomplish, although assisted, it is said, by an Englishman named Nesbit, and by Brunel (afterwards Sir Mark Isambard), and consequently his grant or patent became void. Shortly afterwards, being at Paris as minister from the United States, Livingstone conversed with Fulton on the subject of steam-boats, and intimated his intention of resuming the experiments on his return to America. Fulton then commenced, under his auspices, the experiments which have already been alluded to as exciting the jealousy of M. des Blancs. After several preliminary measures, Fulton and Livingstone completed a boat of considerable size on the Seine, near Paris, early in 1803; but, being too weak to bear the weight of her machinery, she broke through the middle, in a gale of wind during the night, and went to the bottom. To this discouraging accident Mr. Russell attributes one of the excellences of American steam-boats,—the strong and light framing by which, though slender, they are enabled to bear the weight and strain of their large and powerful engines. To remedy this evil, Fulton had to reconstruct his vessel almost entirely, after her shattered hull was raised; and in August of the same year he had her in trying order. This vessel was 66 feet long and 8 feet wide. The speed attained was much less than had been hoped for; but the result of the experiment was such as to induce the projectors to order an engine of Boulton and Watt, with a view to further trial in America. As the boat into which it was fitted was the first regularly established steam-packet, it will be noticed in the second part of our history; but before closing this narrative, allusion must be made to the proceedings of Fulton between the time of these French experiments and his successful enterprise on his return to America. During this time he visited England [FULTON, ROBERT, BIOG. DIV.]; and while here he introduced himself to Symington, from whom he asked for particular information respecting what he had done in steam navigation.

This brief sketch of what may be termed the preliminary history of steam navigation would be incomplete without referring to the experiments of John Stevens, of Hoboken, near New York, who was connected with some of the earliest attempts of Livingstone to introduce steam navigation in North America. Stuart describes a small boat, twenty-five feet long and five feet wide, impelled by a steam-engine with a cylinder of four inches and a half diameter and nine inches stroke, which he tried about New York in 1804. The boiler, which was only two feet long, fifteen inches wide, and twelve inches high, consisted of eighty-one tubes of an inch diameter. This little steam-boat had a velocity of about four miles an hour, or, for short distances, of seven or eight miles an hour. The subsequent vessels of Stevens and his son will be hereafter noticed. About the same time (1804) Oliver Evans, another early American improver of the steam-engine, constructed his "Orukter Amphibolos," or machine for removing mud from docks, with a steam-engine to work the buckets. It was a heavy flat-bottomed boat, thirty feet long and twelve feet broad. Evans constructed this machine at a distance of a mile and a half from the river Schuylkill, and exhibited his long-cherished project of steam locomotion on land by mounting it upon wheels, and connecting them with the engine. After doing this to his satisfaction, he fitted a paddle-wheel to the stern of the machine, and launched it on the river as a steam-boat.

It is not pretended that the above account embraces every project brought forward, or even every public experiment made respecting navigation by steam; but enough has been related to show that its possibility had long been contemplated, and that many persons had expended much time and money upon the scheme before a single steam-vessel was regularly used for the purposes of commerce. Upon the subsequent history of steam navigation it is needless to treat at length; but, before entering upon it, it may be well to state that besides the claims to the invention which have been put forth on behalf of Spain, France, England, Scotland, and North America, one has been made also for an Italian, named Serapino Serrati, in a work published at Florence in 1796, in which it is stated that Watt was the inventor of steam-engines in England in 1787, but that Serrati was "the first not only to conceive the design of a steam-boat, but also to place one upon the river Arno, which runs through Florence." Russell observes that he had no means of testing the truth of this statement, but that, like the narrative of Garay's performances, it may be either true or untrue, without affecting the history of steam navigation; since it is evident that our present system of steam navigation has been in no way derived from either of them.

Fulton returned to America towards the latter end of 1806, and immediately commenced building a steam-boat for use upon the Hudson. This vessel was built at New York, and was launched in the spring of 1807. The engines were mounted and ready for trial by August in that year, engineers from Soho assisting in the work, and when the vessel started, its success became immediately evident. Soon afterwards this vessel, which was named, from Livingstone's residence, the Clermont, made her first voyage from New York to Albany, a distance of about a hundred and forty-five miles; which distance it accomplished at the rate of about five miles an hour.

Satisfactory as was the performance of the Clermont, she did not, owing to the want of proper proportion in the wheels, attain so great a speed as Fulton had anticipated. The dimensions of the boat, which was of a hundred and sixty tons burden, were one hundred and thirty-three feet long, eighteen feet wide, and seven feet deep. Her cylinder was two feet in diameter, and four feet stroke; and the paddle-wheels were fifteen feet in diameter, with paddles four feet long, dipping two feet into the water. These dimensions probably refer to the improved paddle-wheels used subsequent to the first trial, those originally used being too large, so that they dipped too deep into the water. The wheels were of cast iron, and had no support beyond the sides of the vessel, and consequently some trouble was occasioned by their frequent breakage in the earlier experiments. Until his death in 1815, Fulton continued to be actively engaged in building steam-vessels, and at that time he had just completed a large steam-frigate or floating battery, supported by two hulls, with a canal fifteen feet wide between them, in which the paddle-wheel worked. So highly were his services then appreciated, that besides other testimonies of respect, the members of both houses of the legislature wore mourning on occasion of his death.

Fulton had scarcely launched the Clermont before a rival appeared. Stevens of Hoboken had a steam-vessel ready for trial in a few weeks after the triumph of Fulton; but, as the monopoly of steam navigation in the state of New York was secured to Livingstone and Fulton, he could not employ it upon the Hudson, and therefore took it round by sea to the Delaware, thus becoming the first (unless the case of Garay be an exception) to venture to sea with a steam-vessel. To R. L. Stevens, his son, American steam navigation is deeply indebted. He, according to Russell, improved the form of the American vessels, by substituting a very long proportion, with a fine entrance and a fine run, for the full round bows and sterns of Fulton, whose boats were, he says, mere boxes sharpened a little at both ends, which drove before them so large a heap of water as to limit their speed to about nine miles an hour. The improvements of Stevens enabled him to rise to a velocity of thirteen miles an hour. He also adopted a different form of engine from that of Fulton; using cylinders of very long stroke, with upright guides, instead of the old parallel motion, to ensure the accurate motion of the piston, and placing the working beam above the deck, instead of altering the usual arrangement of the machinery in order to keep it below the deck, as done in Fulton's engines and in those commonly used in British steam-vessels.

The practical application of steam navigation in Scotland, though attributable to the experiments of Miller, Taylor, and Symington, at least as distinctly as were the operations of Fulton upon the rivers of North America, did not take place till a few years later, and was in some degree suggested by them. Henry Bell, of Helensburgh, on the Clyde, the individual by whom steam-vessels were first used in Britain for commercial purposes, had been well acquainted with the experiments at Dalswinton and on the Forth and Clyde canal; but he did not take any step for carrying into effect the important scheme of which they proved the practicability, until the proceedings of Fulton, combined with peculiar circumstances in his own case, urged him to do so. Owing to some misapprehension, it was erroneously stated in the Fifth Report of the Select Committee on the Roads from London to Holyhead, in 1822, that Bell went over to America to assist Fulton in establishing steam-boats in that country. In the minute and interesting narrative of Russell, who, from residing in the neighbourhood, had peculiar facilities for obtaining correct information respecting the history of steam navigation upon the Clyde, it is stated that Bell was a house-carpenter in Glasgow for many years, and was rather fond of what are called *schemes*. In the year 1808 he engaged in an undertaking somewhat of this character, by becoming proprietor of an establishment of the nature of an hotel, or bath-house, at Helensburgh, a watering-place on the Clyde, opposite to Greenock. To increase the facilities for reaching this place, and thereby to induce a larger influx of visitors from Glasgow, Bell endeavoured to introduce passage-boats moved by paddles impelled by manual labour; but his experiments failed, and at length he determined upon the construction of a steam-boat to meet the difficulty. Thus his connection with an undertaking of very different character, combined with his correspondence with Fulton, led him to take this important step.

The Comet, built by Bell in 1811, was a vessel of forty feet keel, and ten and a half feet beam; of about twenty-five tons burden, and three-horse power. This vessel began to run regularly between Glasgow and Helensburgh, in January, 1812, and continued to ply successfully during the following summer; her rate of motion was about five miles an hour. The second steam-boat established on the Clyde, the Elizabeth, was commenced as early as March, 1812, and was ready for use about twelve months after. She was the property of Mr. Hutchison, a brewer; but she was built under the direction of an engineer named Thomson, who had been engaged in some of Bell's first experiments. She was of longer proportion than the Comet, being fifty-eight feet long aloft, fifty-one feet keel, twelve feet beam, and five feet deep; and her proportion of power to tonnage was much better, her burden being about thirty-three tons, and her engine of about ten-horse power. The Elizabeth performed the passage of twenty-seven miles, between Glasgow and Greenock, twice a day; and, according to her owner's account, made the voyage in something less than four hours, with a hundred passengers on board, and, in favourable circumstances, in two hours and three-quarters. She accomplished, it would appear from the same statement, a distance of eighty-one miles in one day, at an average rate of nine miles an hour.

Stuart relates that while Bell was engaged in establishing his steamers on the Clyde, a person named Dawson was making similar experiments in Ireland; and that he had, according to his own account, built a steam-boat of fifty tons burden, worked by a high-pressure steam-engine, as early as 1811; which, by one of those singular coincidences frequently met with in the history of inventions, he named the Comet. In 1813, it is added, Dawson established a steam-packet on the Thames, to ply between Gravesend and London, "which was the first that did so for public accommodation, although Mr. Lawrence of Bristol, who introduced a steam-boat on the Severn, soon after the successful operations on the Clyde, had her carried to London (through the canals) to ply on the Thames; but from the opposition of the watermen to the innovation, he was in the end obliged to take her to her first station." If this be correct, the Gravesend steam-packet alluded to must have been overlooked by the author of a pamphlet published in 1831, entitled 'An Account of the Origin of Steam-boats in Spain, Great Britain, and America; and of their Introduction and Employment upon the river Thames, between London and Gravesend, to the present time;' by R. P. Cruden, of Milton by Gravesend, who repeats the statement in his 'History of Gravesend,' (8vo, 1843,) p. 484. He states that the first steam-boat which plied between London and Gravesend was the Margery, of seventy tons burden, and fourteen-horse power; a vessel originally used on the Clyde, where she was built in 1813, by Messrs. Wood of Port-Glasgow, the builders of the Comet and the Elizabeth. She was, it is stated, brought to London from Leith early in 1815, and on the 23rd of January in that year she began to ply between London and Gravesend. This vessel was, in the following year, removed to France, for use upon the Seine; and that tried on the Thames by Dawson was, according to Stuart, sent to Spain, to ply between Seville and San Lucar. Cruden states that the Richmond packet had been employed between London and Richmond in the year preceding the use of the Margery on the Gravesend station.

Among the enterprising individuals by whose exertions steam-boats were established upon the Thames, the name of George Dodd deserves a prominent place, although his history is a melancholy instance of the poverty which often attends the most ingenious inventors. He was, it would appear, the first to undertake a considerable voyage by sea in a steam-vessel. The boat with which this voyage was accomplished was built on the Clyde by Messrs. Wood, and was launched in 1813, under the name of the Glasgow; but was subsequently altered, and called the Thames. She was of seventy-four or seventy-five tons burden, and about fourteen or sixteen horse-power, with paddle-wheels nine feet in diameter. Dodd brought her round to the Thames by steam and sails, experiencing some very rough weather on the way, especially in the Irish Sea. A detailed account of the voyage was published in the 'Journal des Mines' for September, 1815, and subsequently at the end of Dodd's work on steam-boats. It is needless to follow minutely the extension of steam navigation in the British dominions and elsewhere subsequent to the success of Bell and his immediate followers. Bell himself said, "I will venture to affirm that history does not afford an instance of such rapid improvement in commerce and civilisation as that which will be effected by steam-vessels;" and probably there are few at the present time who would not fully acknowledge the truth of his prediction, but it may be interesting to give, from Dodd, an enumeration of the principal steam-vessels in use in Great Britain and Ireland at the date of his work (1818). He states that there were then eighteen steam-boats on the Clyde, two at Dundee, two on the Tay, two on the Trent, two on the Tyne, four on the Humber, two on the Mersey, three on the Yare, one on the Avon, one on the Severn, one on the Orwell, six on the Forth, two at Cork, and two intended to navigate from Dublin to Holyhead. In another part of his work he describes the vessels then in use upon the Thames, of which two, the Richmond and the London, plied between London, Richmond, and Twickenham, and had, he says, carried not less than ten thousand passengers within the last four months. These were built under Dodd's superintendence; and in consequence of having to pass under the bridges, they were made with an apparatus of his invention for lowering their chimneys. These boats experienced much but ineffectual opposition from the watermen, who deemed their use an invasion of their rights. A third steam-vessel designed by Dodd, the Sons of Commerce, intended for use between London and Gravesend, had been used, in the season preceding the publication of his work, between London and Margate, and had once performed the journey, about eighty-eight miles, in seven hours and thirty-five minutes. Her speed, when unassisted by wind or tide, was ten miles an hour. Another boat, the Majestic, plied between London and Margate in 1816. This vessel had been to Calais, and had often towed vessels of seven hundred tons burden down the river. The Regent, one of the early Thames steamers, was accidentally burnt off Whitstable, in July, 1817. Besides these, Dodd mentions the Caledonia, with two engines of fourteen-horse power, which had been from Margate to Flushing, and also on the Rhine; the Eagle, which had a single paddle-wheel in the centre, and failed, he argues, for want of room for the escape of the water agitated by the paddles; the Hope, a small vessel, built at Bristol, which proved a failure; and the Thames, the vessel which Dodd himself brought from the Clyde. In addition to British steam-vessels, it is stated that there were at that time steam-packets and steam luggage-vessels used in Russia, the Netherlands, France, and Spain; and that one was building in the East Indies. In order to give an approximate statement of the progress of steam navigation in the United States about the same period, a few facts may be quoted from the evidence of Seth Hunt, Esq., formerly commandant of Upper Louisiana, before the select committee of the House of Commons appointed in 1817 to consider the means of preventing the mischief of explosion on board steam-boats. This gentleman stated that there were then ten steam-vessels running between New York and Albany, two between New York and the State of Connecticut, and four or five to New Jersey, besides the ferry-boats, of which there were four. On the river Delaware there were also a number of boats, which plied between Philadelphia and Trenton in New Jersey; and others between Philadelphia and Newcastle, and Philadelphia and Wilmington, besides ferry-boats. Some of these were worked with high-pressure engines. There were steam-boats from Baltimore to Norfolk, which passed a part of the Chesapeak, several miles in width; and steam-vessels had been to New London, which is still more exposed; and also up to New Hertford. The Powhatan steam-boat, which was built at New York, had been exposed to a severe gale of wind in the open ocean for three days, after which it arrived at Norfolk, and thence proceeded up the James river to Richmond. The largest steam-boats in America were those upon the Mississippi, plying between New Orleans and Natchez. These vessels, the Etna and Vesuvius, were of four hundred and fifty tons burden, and carried two hundred and eighty tons of merchandise, one hundred passengers, and seven hundred bales of cotton.

The introduction of steam-packets upon the open sea was a favourite object with Dodd. He observes particularly the great importance of their establishment between Dublin and Holyhead, as the intercourse by sailing packets was liable to great delays. They were sometimes, it is stated, more than seventy-six hours at sea, although the distance is only about sixty miles. The use of steam-vessels upon this station was advocated for several years before they were regularly established; and Dodd had, on behalf of himself and friends, offered to bear the expense of two packets for making the experiment, provided the Post-office authorities would guarantee to him the conveyance of the mails, in the event of those packets fully answering his representations; but his offer was not accepted. It has been shown that some sea-voyages were performed at an earlier date; but the regular establishment of ocean steam navigation may be considered to have commenced with the Rob Roy, a steamer of about thirty-horse power and ninety tons burden, which commenced running in 1818 between Greenock and Belfast. This vessel was established by Mr. David Napier, who, says Russell, from the year 1818 until about 1830, "effected more for the improvement of steam navigation than any other man." This gentleman must be distinguished from his cousin, Mr. Robert Napier, of Glasgow, who is also honourably known for improvements of the same kind, but of a somewhat later date. David Napier, according to the interesting narrative of the progress of steam navigation in Britain, given by the above-mentioned writer, ventured at once to establish regular communication between Britain and the neighbouring countries, Ireland and France, by steam-vessels plying even during the stormy months of winter; though, previous to the time of his improvements, such vessels had scarcely ever ventured to sea except in fine weather. In order to make himself well acquainted with the difficulties to be overcome, he took passage, at the worst season of the year, in one of the sailing vessels which formerly plied between Glasgow and Belfast, and which often required a week to perform a journey that is now done by steam in nine hours. After anxiously watching the effect of the waves when the vessel was tossed in a storm, and satisfying himself that there was no insuperable difficulty, he retired contentedly to his cabin, leaving the captain of the vessel puzzled at his strange curiosity respecting the effect of rough weather. He subsequently tried experiments upon the best form of hull for getting through the water with the minimum of resistance; and these led him to adopt a fine wedge-like form for the fore part of his vessels, instead of the round full bow common in those propelled by sails. The Rob Roy, after plying two winters between Greenock and Belfast, was removed from that line, and employed as a packet between Dover and Calais. In 1819 he employed the Messrs. Wood to build the Talbot, of one hundred and fifty tons burden, into which he fitted two engines of thirty horse-power each. This fine vessel, the most perfect of her time in all respects, plied between Holyhead and Dublin; and she was soon followed, on the same line, by another excellent vessel, called the Ivanhoe. In 1821 steam-vessels were regularly established as Post-office packets on that important station. They had been intended merely as auxiliaries to the sailing packets; but they soon superseded them. From the evidence given before the Holyhead Roads Committee in 1822, it appears that even then the intercourse between the two countries had been reduced almost to a certainty; and that while, in the year preceding their adoption, exactly one hundred mails arrived in London after the proper time, there were only twenty-two cases of delay in the first nine months in which the steam-packets were used, although this period included the winter season, during the early part of which the weather was worse than had been known for more than sixty years. The vessels which were built expressly for this purpose were strengthened by diagonal framing upon the plan of Sir Robert Seppings.

The next important stage may be considered to be the building of the "Great Western" at Bristol in 1838, a larger steamer than had then been built, being nearly 1400 tons; and the first voyage by steam across the Atlantic. The tonnage of the Great Western equalled that of the largest sailing merchant ships which had been constructed. She left Bristol, and entered New York harbour under full steam in the extraordinary period of 15 days having on board a surplus of 148 tons of coal. It is true that the Sirius, a smaller steamer, had sailed from Cork before the Great Western left England, and had arrived in safety at New York just before her; but there was this important difference between the two voyages, the Sirius had performed much of her's under sail, while the Great Western had been propelled by steam only. Fourteen years later a large ship called the Australian, built of iron, on the Clyde, left Plymouth (June, 1852) for Melbourne touching for coals at St. Vincent, St. Helena, and the Cape, and anchored safely in King George's Sound, West Australia, on the 20th of August, having performed the whole voyage (including stoppages for fuel) in 76 days. This was the first attempt to reach Australia by steam, and led to the construction of such ships as the celebrated Great Britain, the ill-fated Royal Charter, and other ships of greater perfection. In 1854 a fine American paddle-wheel ship called the Golden Age, astonished our Liverpool builders by her size and power, and gave the first intimation of a change in form likely to become general among ocean steamers. The total omission of a bowsprit and the relief afforded the fore part of the ship as a floating bulk, by the removal of the usual dead wood about the stem and figure-head, was a change deduced from scientific experiments becoming more and more followed. The Golden Age had taken in at one port alone (Tahiti) about 1200 tons of coal, an enormous weight, double that which only 15 years before had been the supply to the Great Western.

Another memorable event in the history of ocean steamers was the voyage of the steam screw ship Argo of 1850 tons, which at about this period circumnavigated the globe, the duration of her actual voyage being only 124 days.

Since this period a number of gigantic ocean steamers have been built for the companies known as the Peninsular and Oriental, the Royal West India Mail, the Cunard, &c. Among these the Persia is the largest of paddle steamers. Some of these magnificent vessels are of about 3500 tons, fitted with exquisite taste and elegance. But the greatest triumph of naval architecture, and the most extraordinary as to size is the Great Eastern, built in 1859 by Mr. John Scott Russell, on the Thames, from the joint designs of himself and Mr. Brunel. This stupendous vessel is of the length of 691 feet on deck, has a breadth of 83 feet and depth of 58 feet, having a gross registered tonnage of 18,914, but said to be capable of carrying 25,000 tons!

The most prominent events in the history of steam vessels having been thus mentioned, a few general remarks will show the actual position of this important subject.

It is, perhaps, impossible to over-estimate the importance of the building of the Great Eastern as an iron ship. In many prior cases steam ships had been saved from foundering by being built of metal. The writer was one who encountered the fearful hurricane of September, 1853, in the Ravensbourne in the North Sea, and long previous experience of the sea enables him to declare that no vessel built of wood could have braved such a prolonged tempest with impunity, inasmuch as the twistings of the frame of the ship must have started trenails and butt ends, to her inevitable destruction, and that of the crew and passengers. The well-known instance of the Great Britain lying a whole winter on shore in Dundrum Bay, exposed to the action of heavy surf, is a powerful fact in favour of iron ships. The introduction of water-tight compartments has also long been a consideration. Steam vessels are greatly strengthened by means of these water-tight bulkheads or transverse partitions in the hull, the general adoption of which, more than any other improvement, increases the safety of steam navigation. In a vessel of the ordinary construction a small local injury from striking upon a rock, from collision, or from any other cause, may occasion the sinking of the vessel, because the water has free access to every part of it. Fire also, wherever it may commence, is pretty sure to spread through the whole length of the boat. The adoption of water-tight bulkheads, to confine the effect of an accident to the particular division of the vessel in which it originates, was suggested by Dodd as early as 1818. He mentions them in p. 220 of the treatise which has been alluded to in the former part of this article, proposing to use them between the engine-room and the cabins; and he states that he intended to introduce them in two boats which he was then building. Whether he did so or not we are unaware; but the adoption of this excellent precautionary apparatus appears to be due to Mr. C. W. Williams, managing director of the City of Dublin Steam-packet Company. A minute description of his bulkheads, and a very satisfactory statement respecting their importance and their efficiency, are given in a communication from that gentleman to the commissioners on steam-vessel accidents in 1839, which is printed in the appendix to their report. He therein states that he first applied water-tight bulkheads in an iron steamer called the Garryowen.

Many instances have occurred in which water-tight bulkheads have saved life and cargo. One of our largest paddle-steamers, in March, 1857, struck an iceberg with such force as would have shivered a wooden ship (or a badly-built iron one) to pieces. As it was, extensive damage to the forefoot caused the fore compartment to fill with water, but so little did it affect the duration of the voyage, that the passengers were unconscious of anything beyond the concussion; nor did the public ever hear of anything beyond the shock, as the next voyage was performed without thorough repair.

In the Great Eastern, not only has a complete system of water-tight compartments been carefully arranged, but these have been longitudinally crossed by fore and aft bulkheads, in such a manner that neither one nor several perforations of her bottom would disable her; and, in addition to these, a considerable portion of her is doubled, so that the outer skin of plates, separated above two feet from a complete water-tight inner bottom, renders her not only the safest, but the strongest ship in the world; for these two separate bottoms are so broad and stayed, and the whole is so contrived, that her construction may be called cellular or tubular. She is a ship perfect on Scott Russell's wave principle [Ship-Building], with 120 feet of midship portion, the sides of which are perfectly parallel; but with this portion the lines of the stem and stern portions are so gracefully combined, that her form is considered the finest afloat.

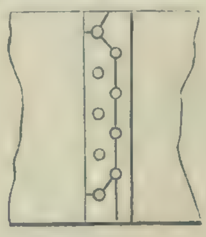
It is difficult for non-nautical persons to comprehend the disparity in size between the Great Eastern and all that preceded her. The best mode of comparing her with other vessels is by noticing that the engine-room of the Great Eastern occupies a cubic space of 5571 tons. Now the Duke of Wellington, a splendid three-decker of 121 guns, is of 3826 tons. Not only, therefore, would the Duke of Wellington stow in the Great Eastern's engine-room, but there would remain surplus space for one of our fine frigates—say, for example, the Orestes, of 1702 tons; and as regards the remaining portions of the Great Eastern, she could, in addition, stow away H.M. ships Waterloo, of 91 guns, with the Goliath, Meanee, and Vanguard, each of 80 guns. And again, whereas the Great Western carried 600 tons of coal as fuel, the Himalaya 1000 tons, and the Golden Age 1200 tons, the Great Eastern carries 10,000 tons. And further, the Great Eastern, when immersed to her load water-line, requires 95 tons to be placed on board her in order to sink her one inch deeper, while the Persia requires only 30.

The great inducement for increasing the size of merchant ships, and which has led in particular to the building of the Great Eastern, is that large ships alone are fit to carry fuel sufficient for a long voyage; coal, when supplied at intermediate stations, being often much augmented, perhaps quadrupled, in cost.

It would be impossible to enter upon the merits of various kinds of vessels now afloat, a large number of which are either fitted with screw or paddle; but we remark that so many vessels are now built of iron, that it has been thought necessary by the committee of Lloyd's, London, to keep a check upon their mode of construction, in defence of the interests of underwriters, by instituting a few regulations as to the dimensions of the framing, plates, &c., of iron vessels. As an example, no vessel of 3000 tons, built of iron, is allowed to have a keel, stem, or stern-post less than 12 inches by 3½. The upright ribs, which correspond with "timbers" in the wooden ships, must be 18 inches apart, and be formed of angle iron of 6½ in. × 4 × ¹¹⁄₁₆. The thickness of plates for garboard strakes to stand as A 1 for six years, ¹⁵⁄₁₆ in.; for nine years, 1 in.; for twelve years, 1¹⁄₁₆ in. Plates between garboard strakes and bilge and the sheer-strakes, for six years, ¹¹⁄₁₆ in.; for nine years, ¹³⁄₁₆ in.; and for twelve years, 1 in. Thickness of plates for beams, ⅝ in.; for bulkheads, ⁹⁄₁₆ in. Angle iron for beam and stringers, or keelsons, 6½ in. × 5½ × ⅝. Thickness of wood for upper decks, &c., 4 in.; while even the sizes of the rivets are determined in proportion to the thickness of plates: as an example, ⅜ in. plates must have rivets at least ⁵⁄₁₆ in. in diameter; ⅝ in. plates, ½ in.; ⅞ in. plates, ¹¹⁄₁₆ in.; and 1 in. plates, ⅞ in. thick. So important an item of the building of an iron ship has the use of rivets been found to be, that very elaborate experiments were in 1857 undertaken by the committee of Lloyds, under the direction of their surveyor, Mr. Mumford, to discover a system of joining iron plates by iron rivets which, while they secured sufficient strength, had no tendency to facilitate the rusting of the plates at the rivet-holes.

A piece of iron plate ⅞ in. thick was subjected to a strain in the hydraulic press, and its breaking strain was found to be about 65 tons to the foot breadth of the plate. Riveted plates were afterwards subjected to strain in the same machine, each rivet being ⅝ in. in diameter, and the rivets were in each plate varied in position. We give the following as illustrations; the whole particulars of each experiment may be seen in the surveyor's report, as published in full in the 'Transactions of the Institute of Naval Architects in 1860':—

Rivets 4 diameters apart.



Lapped plates.
Plate 13¼ in. broad.
Breaking strain 42 tons.
Strain upon 12 inches 38·03 tons.
Fracture through the countersunk plate.

Solid plate.

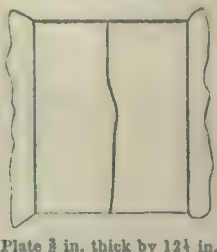


Plate ⅜ in. thick by 12½ in. broad.
Breaking strain 67 tons.
Strain upon 12 inches 65·63 tons.

If we now turn our attention to the arsenals of war, a like series of novelties in steam-shipping awaits us. The question of iron armour for our wooden ships, for ships built entirely of iron, or built partly of iron and partly of wood, or of iron entirely with heavy plate armour, is at the present time an exciting subject. Under the presidency of Sir John Pakington, the Institute of Naval Architects has already considered the question of a screw fleet with advantage; and the veteran Sir Howard Douglas, the Earl of Hardwicke, Captain E. P. Halsted, R.N., &c., have entered upon the subject with characteristic earnestness and professional zeal. To detail what is doing would be premature. It is enough to say that the question of steam-ships was never one of such importance to England as at present. Much might be said of an experiment made by France in building ships coated with heavy armour, like La Gloire. Opinions, however, are so conflicting on various vital points, that, having touched briefly the prominent outlines of the subject, it must be left to the future to chronicle the ultimate success or failure of such experiments.

Two noble vessels called the Warrior and the Black Prince, the one built recently on the Thames and the other on the Clyde, will bear prominently on the future history of steam shipping; a brief description, therefore, of one of these will be interesting, and the more so as a sort of rivalry between ourselves and another country exists in the question which is likely to influence very materially the nature of future naval warfare.

And first, the La Gloire is a fine wooden ship, having a length of 252 feet between perpendiculars, her breadth is 55 feet, and her draft at load water 27½ feet. She is steamer-rigged, having square sails only on her foremast. Her masts are small in proportion to the hull. It is supposed that her ports are only between 6 and 7 feet above water, in consequence of the weight of her defensive armour, which consists of plates of iron about 2 feet wide and 4½ inches thick, extending from stem to stern, and for a distance below water. Her horse-power is supposed to be 900, with screw propeller, and she carries 34 fifty-four pounders on her main deck, and 2 screened heavy shell guns forward. Her ports are 11¼ feet apart on the main deck, a formidable arrangement as compared with every ship that preceded her. But the Warrior is a greatly superior ship, as the following dimensions will prove. (The Black Prince is of the same size and build as the Warrior.)

The length of the Warrior is 380 feet between perpendiculars (420 feet over all), she is of 58 feet beam, 41½ feet depth from spar-deck to keel, 26 feet draft of water, and of the burden of 6177 tons, builder's measurement; fitted with screw propeller, and her engines, constructed by Penn and Sons, are of 1250 horse-power. She is built of iron, but her great peculiarity is that 205 feet of her length is protected by 4½-inch plates of solid iron, backed with two layers of teak timber, one of 10 inches next the armour, and another within that of 8 inches. Her armour extends to 9 feet below load-water line; and at the extremities of the armour-clad portion of her hull, and quite across the ends of the ship at those parts, iron bulkheads of strength equal to the sides (being 4½-inch iron backed with 18 inches teak timber), protect the engines and stores from shots which might enter obliquely from head or stern; and this inclosed space is divided into six water-tight compartments, her two boilers being each in its own separate compartment. In addition to this arrangement inner bulkheads extend all round the protected portion of her hull, leaving passages 3½ feet wide, so that any leakage-water runs below, and this affords room for necessary repairs if injured by shot, &c. Her main deck-ports are about 8½ feet above water (at load-water line), while her ports are 15¼ feet apart; thus ample space is given for working her guns, and for warlike operations. With the spars and sails of an 80-gun ship (but barque-rigged, having no crossjack yard), she will be immensely superior to the La Gloire.

The Warrior is nominally a 36-gun ship, but her guns will be 68-pounders, 95 cwt., for the main deck, 10 Armstrong (70-pounders) on the spar-deck, and 2 pivot 100-pounders (Armstrong's also), one at each end—in all 48 guns; and the number can easily be increased.

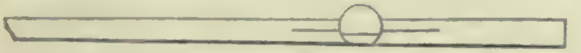
As a comparison, the Warrior's superiority to the La Gloire may be thus briefly stated:—

Ports much higher out of the water, therefore could fight her guns in bad weather when La Gloire could not open her ports.
Her deck is much higher, to facilitate boarding.
Has more space in which to work her guns.
Draws 18 inches less water than La Gloire.
Is less dependent on steam, being nearly full rigged.
Has greater speed, perhaps of 2 knots per hour.
Has heavier armament.
Besides having very superior accommodation for her officers and crew.

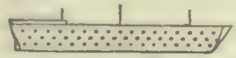
In closing this important detail it should be remarked, that early in 1859 Sir John Pakington, the first lord of the Admiralty, invited the naval architects from the coast to furnish plans for a mail-clad ship, and although numerous plans were forwarded (from Mr. Scott Russell, Mr. Samuda, Mr. Laird, Mr. Napier, &c.), the design adopted originated entirely in the office of the late Controller of the Navy, Sir Baldwin Walker, it being conceived by the Admiralty that such design contained the average proportions and qualifications of all the others.

The last suggestion as to steam vessels for war purposes is that by Captain Cowper P. Coles, R.N., who proposes certain sloping armour plates which shall throw off shot; and also certain modifications in the mode of arming men-of-war so constructed; inasmuch as he would have only one row of guns on the upper deck placed amidships, but placed on revolving, powerfully screened platforms. His highly ingenious proposals have already been well received by the Admiralty, and experiments on a ship fitted by him have been ordered, and will probably commence in a few months.

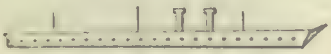
The following outline sketches, drawn accurately to a scale of 240 feet to an inch, give an illustration of the relative sizes of the Great Eastern, H. M. S. Duke of Wellington, the Warrior, La Gloire, the Himalaya, and the Great Britain, some of the most noted among English steam vessels.



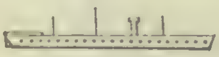
Great Eastern, 691 feet.



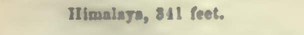
H.M.S. Duke of Wellington, 121 guns, 241 feet.



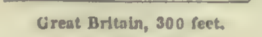
H.M.S. Warrior, 380 feet.



La Gloire, 253 feet.



Himalaya, 341 feet.



Great Britain, 300 feet.

STEARANILIDE. [STEARIC ACID.]
STEARENE. [STEARIC ACID.]

STEARIC ACID ($HO,C_{36}H_{35}O_3$). This body is the most abundant constituent in all solid fatty substances. It exists in them in the state of *stearin*, a combination of stearic acid with the basis of GLYCERIN. The relation which stearic acid bears to other acids, that occur in fats and oils, will be readily seen on perusing the article on FATTY ACIDS. Stearic acid is sometimes met with under the name of *bassic acid* and *stearophanic acid*, and under the name of *anamirtic acid* occurs in the seeds of the *anamirta cocculus*.

Stearin is, for experimental purposes, generally prepared from mutton suet, from a solution of which in hot ether it crystallises out on cooling. By one or two recrystallisations it is perfectly purified. Thus prepared stearin forms white, pearly, lamellar crystals. When quite dry it is not greasy to the touch, and is easily pulverised. It melts when heated to about 144° Fahr., but by repeated fusions becomes more and more dense, and requires an increased temperature for its liquefaction. It is almost insoluble in water and only slightly soluble in cold alcohol or ether. Seven times its weight of boiling alcohol dissolves it, and less than that proportion of hot ether. By destructive distillation it yields oily and fatty hydrocarbons, acetic acid, acrolein, margaric acid, &c. By heating stearic acid with glycerin in closed vessels Berthelot succeeded in obtaining artificial stearins, containing one, two, or three equivalents of stearic acid united with glycerin. [GLYCERIN, *Monostearin*, *Distearin*, *Tristearin*.]

Stearic acid. Obtained by saponifying stearin with caustic potash and then precipitating the stearic acid by the addition of hydrochloric or tartaric acid to the hot solution of the resulting soap. It may be purified by washing with cold alcohol and recrystallising from hot alcohol. It may also be prepared directly from mutton suet by saponifying and decomposing, as above described, and then submitting the product to strong pressure; the greater part of the oleic acid is in this way removed and the remaining stearic acid obtained pure after one or two crystallisations.

Stearic acid crystallises from hot ether in transparent, colourless, lamellæ, having a rhombic outline. Its fusing point is about 167° Fahr.; but it does not resolidify until the temperature falls to about 158° Fahr. At higher temperatures it volatilises and is partially decomposed. It is insoluble in water; its alcoholic solution reddens litmus paper; it slightly decomposes carbonates in the cold, but completely on being boiled with them. A mixture of stearic and palmitic acids melts at a lower temperature than either acid does alone; thirty parts of the former and seventy of the latter fuse nearly 20 degrees lower than the mean melting point of the two. Chlorine and bromine act upon stearic acid, especially when they are heated together, giving rise to chlor- and brom- derivatives. Such a body is chlorostearic acid, containing $HO,C_{36}H_{25}Cl_{10}O_3$. Nitric acid oxidises it to suberic, pimelic, adipic, succinic, capric, œnanthylic, caproic, and other acids. Anhydrous phosphoric acid removes from stearic acid the elements of two equivalents of water, and leaves a brittle, obscurely-crystalline mass, having the composition ($C_{36}H_{34}O_2$). Perchloride of phosphorus also acts energetically upon stearic acid. A mixture of stearic acid and glycerin maintained at 212° Fahr., and saturated with hydrochloric acid gives rise to *stearochlorhydrin*, a crystalline body containing ($C_{42}H_{41}ClO_6$).

Stearone, *stearene*, or *margarone*, is a colourless crystalline body produced on distilling stearic acid with one fourth its weight of quick lime. It fuses at 171° Fahr. and resolidifies at 162° Fahr. Its composition has not been satisfactorily determined.

Stearates are combinations of stearic acid with bases, and the compounds, like those of the other FATTY ACIDS, are termed *soaps*. Stearates are mostly fusible and decompose when strongly heated. Those of the alkalies are readily formed on heating stearin with the alkali, as in the ordinary method of making soap. From the alkaline stearates other stearates may be formed by precipitation with a soluble salt of the metal whose stearate is required; the alkaline stearates being soluble in water, the stearates of other metallic oxides being insoluble. The *neutral stearate of potash* contains ($KO,C_{36}H_{35}O_3$) the *acid stearate* ($KO,HO,2C_{36}H_{35}O_3$). *Stearate of lime* ($CaO,C_{36}H_{35}O_3$). *Stearate of silver* ($AgO, C_{36}H_{35}O_3$). *Stearate of ethyl* (stearic ether) ($C_4H_5O,C_{36}H_{35}O_3$).

Stearanilide or *phenyl-stearamide* is obtained on distilling stearic acid with excess of aniline. It crystallises in needles and contains

$$\left(N,\left\{\begin{matrix}C_{36}H_{35}O_2\\C_{12}H_5\\H\end{matrix}\right.\right).$$

For the economical applications of stearic acid, see CANDLE MANUFACTURE; SOAP.

STEARIN. [STEARIC ACID.]
STEAROCHLORHYDRIN. [STEARIC ACID.]
STEARONE. [STEARIC ACID.]
STEAROPHANIC ACID. [STEAROPHANIN.]

STEAROPHANIN. ($C_{38}H_{36}O_4$). *Anamirtin.* A fatty matter described by Francis as existing in the *Anamirta Cocculus*. By saponification it yields *anamirtic* or *stearophanic acid*, which Hanitz considers to be identical with *stearic acid*.

STEAROPTEN. Volatile oils, as obtained by distillation from plants, appear, like expressed oils, to consist of two substances; one solid, which has received the name of *stearopten*, and the other liquid, called *elaopten*: the former generally crystallises when the oil has been long kept.

Camphor is the most remarkable substance of the class of stearoptens. It is obtained by distillation with water, and in the plant is mixed with camphor-oil, from the gradual oxidation of which it appears to be produced. [ESSENTIAL OILS.]

STEEL. [METALS, *Iron.*]

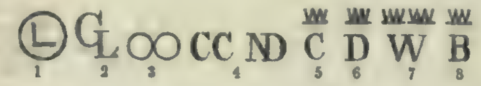
STEEL ENGRAVING. [ENGRAVING.]

STEEL MANUFACTURE. Iron possesses qualities which render it applicable to innumerable purposes in the arts; but there are some uses for which it is not sufficiently hard, and this defect is supplied by converting it into steel.

At Eisenärzt in Styria the manufacture of steel has been carried on ever since the 8th century, and yet the exact nature of the operation is perhaps even now imperfectly understood. It is generally admitted that steel is an intimate compound of iron and charcoal; for soft iron contains a considerable portion of charcoal, and it is by no means clear that the quantity is increased in the process of steel-making. Therefore we must conclude that some more intimate union is effected between them when iron is converted into steel. On this point we shall touch again after describing the manufacture.

Hitherto Swedish and Russian bar-iron have been almost exclusively employed in the manufacture of the best steel; the preference given to this iron is decided, though from what cause it arises has not been satisfactorily made out. We may, however, remark that the foreign iron used is made from magnetic iron-ore with charcoal; while British iron is obtained mostly from the impure carbonate of iron, called argillaceous iron-ore, or from hæmatite, which is a peroxide of iron, and both of these are reduced by employing coal, or coke prepared from it.

Bar-Steel is made, with few exceptions, from the Swedish and Russian iron, the bars of which are marked *hoop l* (1), *gl* (2), and *double bullet* (3); these are the best kinds. Iron of lower quality is also used, such as (4), which is a Russian iron, and *c and crown* (5), *d and crown* (6), which are Swedish irons. There is a medium quality, namely, *w and crowns* (7), *b and crown* (8); these also are Swedish.



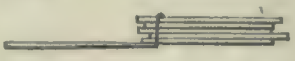
These steel irons are imported almost exclusively by English merchants residing in Hull. The limited quantity of the fine iron allowed to be produced from the mines of Danemora in Sweden accounts in some degree for the high price at which they are sold.

Bar-Steel. The usual operation in large steel-works is first to cut the bar-iron into certain lengths. The closed vessels in which the bars are heated are usually twelve feet in length, and divided into two cells or troughs, on the bottom of which the workman strews charcoal to the thickness of about an inch. Upon this he places on their flat side a layer of bars; then about three-fourths of an inch more of charcoal is added; on this another layer of bars; and so on till the troughs are filled. These are then covered with a ferruginous earth coming from the grinding-stones, called wheelswarf, to the thickness of about eight inches. All the apertures of the furnace are closed with loose bricks and plastered over with fire-clay. The fire is then lighted, and in four days and nights the furnace is at its full heat; at which it is kept for several days, according to the degree of hardness required. In order to be able to test the progress of the carbonisation, a hole is left in one of the troughs near the centre; three or four bars are placed in the furnace in such a manner that the ends come through this opening, and after the sixth day one is pulled out. If the iron be then not sufficiently carbonised, the heating is continued from two to four days longer. A bar is drawn every two days; and when the iron is completely converted, the fire is heaped up with small-coal, and the furnace is left to burn out. It requires from this period fourteen days' time to cool sufficiently to allow a person to go in and discharge the steel. The cells or troughs must be kept completely air-tight; the smallest crack will open when the furnace is hot, and admit the air: this of course frustrates the object of the operation, and any steel which has thus suffered is placed aside to be reconverted. It is of the greatest importance to give the iron the exact quantity of carbon required and no more. For coach-springs, the iron must *not* be converted to the centre. For common cutlery, sheer steel, and for purposes where steel has to be welded to itself or to iron, the conversion should be low, and gradually disseminated throughout the whole thickness of the bar. For double sheer steel, the conversion should be somewhat harder than the preceding. For files, and all instruments where resistance or fine cutting edges are required, the conversion should be hard, and the iron fully carbonised throughout the bar.

No definite rules can be laid down to enable the uninitiated to judge of the temper or degree of hardness of a bar of steel; but by habit workmen soon acquire the means of distinguishing between the different degrees of hardness of two pieces of steel. This knowledge of the degree of temper is of great importance to the steel maker; for a file, made from soft steel which would be valuable for welding purposes, would be useless in the arts; while a coach-spring made from steel hard enough to make a file could not be applied to its intended purpose.

A converting furnace contains generally fifteen tons of iron; and there are some large enough to hold eighteen to twenty tons. The bar-steel, when discharged from the furnace, is partially covered with small raised portions of the metal; and from the resemblance of these to blisters, the steel is called *blistered steel.* It has been found by the experiment of placing a bar of Swedish and one of Staffordshire bar-iron in the same furnace, that the former was much blistered, while the latter had scarcely any blisters larger than a pea. At one time it was common for the steel-maker to receive orders for steel *well blistered.* This arose from a mistaken idea regarding the perfection of the steel; it being supposed that the more it was blistered, the more it was carbonised, and consequently that its quality was indicated thereby; now, however, manufacturers are better informed, and steel so blistered is complained of.

Bar-steel as it comes from the converting furnace is used for various purposes without refining; those parts which are free from flaws and blisters are broken out and hammered or rolled to the sizes required by the manufacturer for files, edge-tools, table knives and forks, coach-springs, and a great variety of common agricultural implements. It is also manufactured into what is called *single* and *double sheer steel*; for this purpose the converted bar is selected of an equable degree of hardness, and broken into pieces of about two feet in length; these are taken to the forge, heated to a full cherry red, and hammered into bars two inches by three-quarters of an inch in thickness; six of these pieces are put together and kept firmly so by a hoop, which is fixed at the end of a handle, thus—



They are then placed in a hollow fire urged by a soft blast, and heated gradually up to a full welding heat, during which the workman covers the surface with clay beaten very fine; this runs over the surface, and to some extent prevents oxidation. When fully heated, they are placed under the hammer, carefully welded together, and drawn into a bar of about two inches square at the same heat; the other end is then put into the fire and welded in the same way. This is termed *single* sheer steel. It is made *double* by nicking the bar in the middle and doubling it together, giving a second welding heat, and drawing it out as before to a bar of about two inches square; it is then *hammered, tilted,* or *rolled* to the size required; by this process *bar-steel* becomes more homogeneous, of a finer texture, and any instrument made of it will receive and retain a finer edge; the steel is also rendered much tougher, which condition is supposed to arise from the abstraction of a small portion of carbon, and the mechanical elongation of the fibre by these doublings, &c.

In Sheffield, where the steel manufacture is carried on to a larger extent than in any other town in the world, many manufacturing firms confine their operations exclusively to those above described: namely, making *bar* steel, in the two forms of *blister* and *sheer,* without including the making of *cast*-steel, or the fashioning of steel goods. The sheer-hammers, employed in the production of sheer steel, are very massive machines, having iron heads of twenty cwts. or more, faced with steel. The blows of these hammers, acting on heated bars of steel, greatly change their character; the blistered steel loses all its blisters and flaws, acquires a uniformity of character throughout, and becomes much more malleable and tenacious. According to the degree in which it is welded or sheered, so does the steel become applicable to a large number of practical purposes.

Cast Steel is the steel employed for the best goods. Cast-steel was first made by Mr. Huntsman, at Attercliff, near Sheffield, in 1770; since which time the manufacture of it has very much increased. It is steadily superseding the use of bar or sheer steel, on account of the equality of its temper, and the superior quality as well as beauty of the articles which are made of it. The process adopted is that of taking bar steel converted to a certain degree of hardness and breaking it into pieces of about a pound each; a crucible charged with these is placed in the melting-furnace, similar to that used by brass-founders. The furnaces are 20 inches long by 16 inches wide, and 3 feet deep. The most intense heat is kept up for two hours and a half or three hours, coke being used as fuel. When the furnace requires feeding, the workman takes the opportunity of lifting the lid of each crucible and judging how long the charge will be before it is completely melted. All the crucibles are usually ready about the same time. They are taken out of the furnace, and the liquid steel is poured into ingots of the shape and size required: the crucibles are immediately returned into the furnace; and when the contents of all have been poured into the moulds, the crucibles are again charged. They are used three times, and then rejected as useless. The ingots are taken to the forge-tilt or rolling-mill, and hammered into bars or rolled into sheets, as may be required. The celebrated *wootz,* or Indian steel, is cast-steel; but it is generally so imperfect as to resemble cast-iron rather than cast-steel. It is, however, made of iron obtained, as the Swedish is, from the magnetic ore. Wootz is made by the natives from malleable iron, packed in small bits with wood in crucibles, which are then covered with some green leaves and clay: about two dozen of these crucibles are packed in one furnace; they are covered with fuel, and a blast given for about two hours and a half, which terminates the operation. When the crucibles are cold, they are broken, and small cakes of steel are obtained in the form in which it comes to England.

This making of cast-steel is a remarkable operation. The heat of the furnaces is believed to be higher than any other known in English manufactures. The ingots weigh from about 40 to 200 lbs. each, according to the purposes to which they are to be applied. No less than four to five tons of coke are needed for smelting one ton of steel.

The *tilting* of steel is a process of hammering, mostly for cast-steel. The steel is heated to a certain temperature, and hammered all over for a considerable time; this closes the pores, and renders the metal as close and compact as possible. The steel for the best articles is both cast and tilted. *Case-hardening* is an operation whereby articles made of malleable iron or cast-iron are superficially converted into steel by heating them with charcoal in a crucible.

Relations of Steel to Iron.—The steel manufacture is just now in a transitionary state; several new processes of a highly curious nature have been introduced by Heath, Clay, Bessemer, Uchatius, and others, not fully successful, perhaps, but significant of the future. Most of these depend on a study of the relations between iron and steel, in a way which we shall briefly describe.

With respect to the composition of steel and the nature of the mixture necessary to constitute it, differences of opinion have long existed. The question even now is considered by some as hardly decided, whether carbon is indispensably necessary to its formation, and whether certain substances or metals, especially silicon, may not give rise to it; and it is generally admitted that phosphorus is always present. Berzelius mentions iron containing manganese as particularly eligible, and yet analyses show that this metal is not present in steel in most cases. An experiment performed by Mr. Pepys in 1815, seems not only to prove the necessity of carbon, but also that the diamond is capable of producing the same effect. In order to get rid of the objection that the carbonaceous matter of a common fire might supply carbon when iron and diamond were heated by means of it, he placed diamond-powder in a piece of pure soft iron wire; and having properly secured it, he heated it by means of voltaic electricity: after a few minutes' heating, the diamond had disappeared, and the interior surface of the iron was converted into perfect blistered steel, which, being heated to redness and plunged into cold water, became so hard as to resist the file and scratch glass. Some years since a method was discovered by Mackintosh of converting iron into steel by means of the carbon of carburetted hydrogen gas. Gay Lussac found that during fusion steel loses much silicon and a little carbon. Brande has found that when the carbon has fallen short of one per cent., the steel was deficient in hardness; and when it has exceeded this proportion, the dies have split or not stood their work. He states, at the same time, that minute quantities of other bodies appear to influence the quality of steel; and that unless it contain phosphorus it cannot be depended on for the manufacture of dies in coining. Dr. Thomson examined some cast-steel furnished him by Mr. Buttray, a steel-maker near Glasgow. The general result of his trials gave him a composition which approaches 20 atoms of iron + 1 atom of carbon; and this he thinks likely to be the constitution of cast-steel, an opinion corroborated by the fact above stated by Mr. Brande. Mr. Faraday and Mr. Stodart published in the 'Phil. Trans.' for 1822 a valuable series of experiments on alloys of steel, from which it appears that by combining steel with other metals its quality is improved. A very minute addition was found sufficient to produce a good effect: thus one 500th of silver gave an alloy harder than cast-steel; one 100th of nickel gave a very hard alloy, susceptible of a fine polish; alloys of rhodium and platinum were also formed; and these, with the alloys of iridium, osmium, and palladium, formed the most valuable compounds.

Mr. Binks, in a paper read before the Society of Arts in 1857, on the nature and properties of steel, described the experiments which had led him to the following conclusions: That the substances whose application to pure iron convert it into steel, all contain carbon and nitrogen; or that nitrogen has access to the air during the process. That carbon alone added or applied to pure iron, does not produce steel; and that neither does nitrogen alone produce it. That it is essential for both carbon and nitrogen to be present. That both exist substantially in steel after its conversion. That such presence is the real cause of the distinctive physical properties of steel from those of iron. That presumptively, though not demonstratively, the form of combination is that of a triple alloy of iron, carbon, and nitrogen.

It has for many years been believed in England, that Swedish iron derives some of its valuable steel-making properties from the presence of a small quantity of manganese; hence the question—might not manganese be profitably added to English iron? Mr. Heath took up the subject, spent a fortune upon it, greatly enriched Sheffield, and died broken-hearted. In 1839 he devised a mode of combining carbon with manganese, to produce a carburet, which converted English iron into very good steel. The manganese appeared to him to act as a sort of detergent, taking away certain impurities from the iron. Unfortunately for his interests, he *improved* the process; he put into the furnace the elements of the carburet (carbon and manganese) instead of the carburet itself, thereby lessening the expense. He neglected to obtain a second patent for this improvement; the Sheffield manufacturers saw the flaw, made the new steel without paying him any royalty and defied him. The suit of Heath *v.* Unwin, carried on for eleven years, in all the various forms known to English law and equity, ruined Mr. Heath, who died in 1850. His widow succeeded in obtaining a small interest arising out of the patent, but quite disproportionate to the importance of the invention. Mr. Webster has stated that, between 1839 and 1855, buyers of Sheffield cast-steel goods benefited to the extent of *two millions sterling* by the lowering of prices due to Mr. Heath's process.

Steel is of a lighter gray than iron. It is susceptible of receiving a very high polish, and this is greater as the grain is finer. When steel is hardened its volume is increased. When heated to redness, and slowly cooled, it is scarcely harder than iron; but by very rapid cooling it becomes hard, and so brittle as to be readily broken. The fracture is usually fine grained. In ductility and malleability it is much inferior to iron, but exceeds it greatly in elasticity and sonorousness. It may be subjected to a full red heat, or 2786° Fahr., without melting, and is therefore less fusible than cast-iron, but much more so than wrought-iron. Pieces of steel which have not been cast may be readily welded together or with iron; but after casting, the operation is more difficult. In order to give to steel the different degrees of hardness required for various purposes to which it is applied, it is subjected to the process of *tempering*. The higher the temperature to which it is raised, and the more sudden the cooling, the greater is the hardness. Thus when immersed in mercury the hardness is greatest, on account of the good conducting power of the metal, and its consequent ready abstraction of heat. After this comes acidulated water, salt water, common water, and lastly oily or fatty bodies. It is found that, according to the degree to which steel is tempered, it assumes various colours, and formerly these colours served as guides to the workman; now, however, a thermometer, with a bath of mercury or of oil, is employed, and the operation is performed with a much greater degree of certainty. Into this bath the articles to be tempered are put, with the bulb of the thermometer graduated up to the boiling-point of mercury. The tempering heat varies from 430° Fahr. (for lancets) to 600° (for pit saws).

Puddled and Bessemer Steel.—Arising out of the inquiries concerning the relations between iron and steel, several new modes of making steel have recently been introduced or proposed. Hitherto, most English steel has been made by the *converting* process, already described; but on the Continent it is more usual to adopt what is called the *raw* method, puddling the metal in a charcoal furnace. The English method *raises* the amount of carbon in or with *bar*-iron up to about 1 per cent.; the Continental method *lowers* the amount of carbon in or with *pig*-iron from 4 to 1 per cent. Riepe's method, patented in 1850, and worked some time by the Low Moor Iron Company and the Mersey Steel Company, is for making a kind of steely iron by the puddling process, good enough for most common purposes—hard and unyielding, or soft and silky, according to the extent to which the process is carried. To produce this steel, pig-iron is thrown into a puddling-furnace [FURNACE; IRON MANUFACTURE], together with a little iron slag, salt, clay, and oxide of manganese; the molten metal is worked or puddled beneath the scum, and is worked up into balls or blooms at a certain stage. Captain Uchatius, engineer of the Imperial Arsenal at Vienna, has devised a method of making steel in which (as he thinks) English iron would suit as well as Swedish or Russian. He brings the iron to a granular state, by running it from a furnace into agitated cold water. These grains are mixed with some cheap oxygen-yielding material, such as spathose iron-ore, put into a crucible, and melted in a cast-steel furnace. The pig-iron gives up some of its carbon and its earthy impurities to the oxygen, and becomes steel. The smaller the granules, the softer the steel. Uchatius produces 25 lbs. of steel from 24 lbs. of granulated iron, 4 lbs. of spathose ore, 4 lbs. of oxide of manganese, and a little clay. Sir F. Knowles has introduced a method in which a retort instead of a crucible is used; while the crude iron is mixed with hot gases rich in carbon. The processes of Uchatius and Knowles seem better adapted for the laboratory than for large manufacturing operations. Other modes of producing steel directly from the crude iron have been introduced, with varying success, by Clay, Saunderson, Plant, Nasmyth, Mortier, and others.

But of all the novelties connected with the steel manufacture, those by Mr. Bessemer have attracted the most notice within the last few years. He has taken out five or six patents on the subject. In his hands the difference between iron and steel is simply one of degree, for it is not easy to say where Bessemer iron ends and Bessemer steel begins. It was at the Cheltenham meeting of the British Association, in 1856, that the process first attracted attention. Mr. Bessemer conceived that pig-iron might be converted into malleable iron, and then into steel, without any additional consumption of fuel. Pig-iron contains more carbon than the others; and if oxygen could be made to burn a portion of this away, the object would be accomplished. How, then, to expose molten pig-iron to the action of oxygen? He decided that a *blast* would best effect this. He formed a fire-brick furnace of small size, with *tuyère* holes near the bottom, and two larger holes half-way up. Molten pig-iron flowed at once from a blast-furnace to this small furnace or cylinder, and a blast was driven into the cylinder. A violent commotion ensued, and an intense heat resulted from the combination of the oxygen in the blast with the carbon in the molten mass. Volumes of flame and a few sparks were produced, and then a sort of eruption of slag. Flames again appeared; for some of the oxygen formed an oxide with some of the iron, and acted as a kind of solvent for sulphur and earthy matters. The pig-iron lost about 12 per cent. of its weight during this process. The rich slag thrown out might be afterwards treated with carbon gases, and made to yield more iron. When the flames and sparks had subsided, a plugged hole was opened, and the metal poured into an ingot-mould, without leaving any cinder or oxide. The process took little more than half an hour, and no fuel was used. While in the cylinder, the metal was not a mere pasty mass, it was a boiling fiery fluid. At a certain stage, the iron became crude steel. By continuing the boil, more carbon was driven out, and purer steel resulted. In short, any medium between the softest iron and the hardest steel might be produced by varying the duration of the process. One kind, called by Mr. Bessemer *semi-steel*, is more elastic, harder, and stronger than bar-iron, but not so hard and fine as steel; it is useful for light and strong purposes; it is more difficult to roll than iron, but is stronger and more durable, and is therefore considered to be cheaper in the end.

In the three years next following this announcement of Mr. Bessemer's invention, the comments took the whole range between the highest praise and the most marked disapproval. The inventor and his friends claimed for the novelty a diminution of labour, time, and cost; the production of a metal more homogeneous than by the common method; no residue of wasteful slag; and the power of producing ingots of any weight from one to seven or more cwts. The Llanelly Tin-Plate Works supplied Mr. Bessemer with some pig-iron such as they used for producing the best sheet-iron: he converted it into a soft ingot, which was wrought at a white heat into a slab by the force of a steam-hammer, and then rolled into very good sheet-iron for tin-plate. Mr. Adams stated that an amateur might easily make a bit of steel, by melting 4 ozs. of cast-iron in a crucible, pouring it into the bowl of a large tobacco-pipe, and using the stem as a blow-pipe. On the other hand, most of the manufacturers found fault with the Bessemer process. Some of them said that, although the process removes the carbon and silicon more completely than the ordinary method, and the sulphur about as well, it leaves the phosphorus untouched, which they regarded as a fatal blot. Others made trial of the process, and declared the iron or steel produced to be bad. In 1859, after patenting several modifications of his plan, Mr. Bessemer described his process, in a somewhat altered form, before the Institute of Civil Engineers. He had been endeavouring to get rid more completely of the sulphur and phosphorus. He used Swedish iron instead of English for the best steel, poured the molten metal into cold water instead of into a large mould, re-melted it, and finally poured it into small moulds. Other changes had been made in the apparatus and the process. Some of the ingots exhibited possessed wonderful tensile power. A bar 3 inches square was bent round until the outer curve was lengthened from 12 to 16¾ inches, and the inner lessened from 12 to 7½ inches, cold, and without a flaw. Four iron rods, 1¼ inches diameter, were twisted cold into a cable; the rods stretched one foot in four during the process, and thinned out in inverse proportion. A steel bar, 2 inches square, was twisted cold into a spiral at an angle of 45°. A round steel bar was hammered cold into the form of a horse-shoe.

At the present time, the Bessemer process is under probation. Works have been erected at Sheffield to put it in operation; and similar establishments have been founded in several Continental states. By this means the system will obtain that which alone can determine its value—a fair trial on a large scale. Persons of moderate views believe that the semi-steel will become useful for railway purposes, as being harder than bar-iron, and for marine engine-work, because it is lighter than iron for equal strength. How far fine steel can be profitably produced, without the converting process, is still a disputed point.

In 1853, Sheffield had 160 steel-converting furnaces, and 1495 cast-steel "holes"—about 16 holes to a casting-furnace. Of the 20,000 to 40,000 tons of Swedish iron annually imported, nearly all goes to Sheffield to be converted into steel. Including Russian and English iron, it is supposed that about 50,000 tons are annually made into steel, of which 30,000 tons are cast-steel. The value of this quantity is roundly estimated at about 1,500,000*l.* yearly.

STEELYARD. [WEIGHING MACHINE.]

STEELYARD, MERCHANTS OF THE, a body of aliens who enjoyed various commercial privileges in England from an early period to the middle of the 16th century. "The emperor's men," mentioned in some ordinances of Ethelred II. (A.D. 978-1016) as trading to England, were the predecessors of the merchants of the Teutonic Guild. In 1220 the merchants of Cologne had a hall or factory in London, for the legal possession of which they made an acknowledgment to the king. "It seems that this Gildhall, by the association of the merchants of other cities with those of Cologne, became in time the general factory and residence of all the German merchants in London, and was the same that was afterwards known by the name of the German Gildhall ("*Gildhalla Teutonicorum*"). (Macpherson, 'Annals of Commerce,' i. 383.) In 1235, Henry III. gave them permission to attend fairs in any part of England, and also to buy and sell in London, saving the liberties of the city; and they were exempted from several customs and payments. In the 15th century we find the Hanse merchants engrossing the privileges of the above ancient incorporation, Cologne being a member of the League, and the whole of the German merchants resident in London probably belonging to one or other of the Hanse towns. At least, after 1475, they had but one factory in London, which was the Steel-yard, or Steel-house, as it was sometimes called, situate a little east of Dowgate, between Thames Street and the river. The Thames-street front was fortified with three portcullised gateways; and the whole was inclosed by strong walls, within which, more than once, and especially on the irruption of Wat Tyler's mob in 1381, the Hanse merchants saved themselves, while the Flemings and other foreigners fell victims to the national prejudice. In the interior was the great hall, adorned with pictures by Hans Holbein, in which the corporation held their councils and partook of their feasts. On the west side of the hall was a garden, adorned with vines and rare fruit trees. The Thames front was a quay, with all the conveniences then known for embarking or disembarking goods. The remainder of the area was occupied by lofty warehouses and streets of booths for the reception and display of the necessaries and luxuries imported from the north, south, and east,—fine cloths, wines, silks, dried fruits, spices, with hemp, tallow, furs, salt-fish, and iron. Strict order was preserved in the building, whose gates were shut at nine in the evening; and to the corporation was entrusted the care and repair of Billingsgate; every master being under an obligation to provide harness for war, the same as a native. The old building was destroyed in the fire of London in 1666. That which succeeded differed little from the other erections in its neighbourhood. The Steelyard was in the parish of Allhallows, at which church the members attended, and which they embellished with painted windows. After the fire of London, on the rebuilding of the church, they contributed the carved oak screen which still separates the choir from the nave. In 1673, the inconvenience of attending a service in a foreign language induced them to petition for one of the abandoned churches, and that in Little Trinity Lane was granted to them, which has thenceforward been used by the German residents in London for divine service in their own tongue. In 1475, Edw. IV. entered into a treaty with the Hanseatic League, by which the privileges of the London factory were placed on a more secure foundation, instead of being granted only for a short period, and being at times curtailed, and even occasionally suspended. By way of settling former disputes, it was thought worth while to pay them 10,000*l.*, or rather to remit customs duties on their goods to that amount. The king was to appoint two or more judges to act without the ordinary legal formalities in all civil and criminal cases between the Hanse merchants and English; and similar regulations were to be adopted in reference to English subjects residing at the Hanse towns. The fee simple of the Steelyard was conveyed by this treaty; also the Steelyard at Boston, and a house at Lynn. Under this treaty and their old charters, the Hanse merchants of the Steelyard were enabled to monopolise certain branches of trade, in which they were exempted from duties payable by other traders; and by their combination and capital, they were doubtless formidable competitors in other branches of foreign trade; but though the activity of foreigners might be tolerated while native capital was wanting, yet a trade from which English merchants were virtually excluded could not possibly be permanent. The industry and energy of the English trader made him a formidable competitor. He not only, in spite of the troubles of the wars of the Roses, exerted himself to supply domestic wants, but he actually, as is noticed above, had pushed himself into the traffic of the Baltic. In addition, the requirements of commerce had introduced the use of larger vessels; which could not well be adopted by the Hanse merchants, as they could not come above London Bridge. All things were working against the interests of the Steelyard.

In 1505 a rival interest was created, by a charter granted to the Company of Merchant Adventurers for trading in woollen cloth to the Netherlands. The merchants of the Steelyard were bound in heavy penalties not to interfere with the trade of this new incorporation, which soon became a powerful rival, not only to the German merchants, but to the merchants of the staple. In 1551, various allegations of the Merchant Adventurers, with the counter-statements of the merchants of the Steelyard, were put into the hands of the solicitor-general and the recorder of London, upon whose report the council came to a resolution that the Steelyard merchants had forfeited their privileges, their charters being contrary to the laws of the realm. The council reported that no particular persons or towns being mentioned in these charters, the corporation had extended their privileges to whomsoever they pleased; that English subjects had not enjoyed reciprocity of privileges in the Hanseatic towns; that their English trade was no longer confined to the Hanse towns; that they had engrossed almost the entire trade carried on by foreigners in the kingdom; lastly, that they had reduced the price of wool, and also of corn by their importations of foreign grain. The articles which they imported, besides grain, are stated to have been cordage and other naval stores, flax and hemp, linen, cloth, and steel. The English Merchant Adventurers flourished on the ruin of the older incorporation, which however continued to linger until 1597, when the Emperor Rudolph having ordered the factories of the English Merchant Adventurers in Germany to be shut up, Queen Elizabeth directed the Lord Mayor of London to close the house occupied by the merchants of the Steelyard. The buildings and site of the Steelyard, however, remained in possession of the towns of Hamburg, Bremen, and Lübeck, as representatives of the old Hanse corporation, till 1853, when, having no use for them, they sold the property, for which it is said they obtained 72,000*l.*

(Strype's *Eccles. Mem.*, iii. 77; Anderson's *Commerce;* Macpherson's *Commerce;* Dr. Reinhold Pauli's *Bilder aus alt England*, which contains an essay on the Steelyard.)

STEERING APPARATUS. Various contrivances have been made of late years, some of great ingenuity, to remedy the inconveniences of the steering-wheel so long in use. Larger vessels requiring more powerful apparatus for moving the rudder, many patented inventions have appeared which have introduced the use of cogs and screws; but no one has yet succeeded in effecting such results as would warrant its general adoption. One, however, that by which the steering-wheel is situated in the fore part of the vessel, its motion being communicated to the rudder by ropes, chains, or rods, was used by Symington in his tug-boat upon the Forth and Clyde Canal, about 1802; but whether its subsequent adoption in North America is in any degree to be attributed to that circumstance, we are not aware. The peculiar arrangement of the river steamers of America, which have the engines and some of the cabins on deck, combined with their great length, renders it impossible for the steersman, if in the situation usual in the steam-vessels of this country, to see his course; and, therefore, he is usually elevated on a platform near the bow.

STELE, the name of any upright column, or tablet, on which were engraved decrees, funereal and other inscriptions, sometimes decorated with subjects in relief. The Egyptian steles, called *hutu*, placed in the tombs, have, during the 6th and 12th dynasties, scenes of family worship; but under the 18th and subsequent dynasties adorations to deities are represented: at all periods they have hieroglyphical inscriptions, dedications to sepulchral deities entreating certain benefits for the deceased, and other religious formulæ, or even family registers. Some are dated in the reign of the king under whom the deceased died. Other steles, dedications of temples, or invocations to deities on behalf of different monarchs, were placed in the adyta of temples. Granite, basalt, and calcareous stone were chiefly used. The Assyrian steles have generally a bas-relief of the monarch by whom erected, and a long account of his conquests, in cuneiform characters. The Greek sepulchral steles are often ornamented with figures of various deities to whom they were dedicated, scenes of family repasts, or last adieus, representations of the deceased, or floral and architectural ornaments, and inscriptions commemorative of the deceased. Public acts, treaties, and religious dedications, were often registered on steles. They are generally made of white, although occasionally of coloured, marbles. Some Carthaginian steles have dedications to Baal Hammon and Tanath, and representations of this goddess. (Layard's *Nineveh;* Stackelberg, *Die Gräber der Hellenen;* Hincks, *On the Egyptian Stele.*)

STELLIONATE, a word derived from *stellio*, the name of an animal of the lizard kind, mentioned by Pliny ('Hist. Nat.', l. 3, c. 10), and by Virgil ('4 Geor.', 243), is a term used in the Roman law to denote all such crimes, in which fraud is an ingredient, as have no special names to distinguish them, and are not defined by any written law. In general, wherever a civil action might be brought on the ground of fraud, there might be a criminal prosecution for stellionate. The term however is chiefly applied to cases where a person sells, exchanges, or transfers to one, property with respect to which he has already entered into a contract with another. It is also applied to cases of pledging another man's property, substituting base for precious metals, dealing in counterfeit or adulterated goods, and generally to the practice of any species of imposture. The punishment of stellionate was of necessity discretionary. Where the criminal was a person of distinction, the ordinary punishment appears to have been temporary banishment and degradation from his rank; and where he belonged to the lower orders, it seems to have been competent to inflict any punishment short of condemnation to work in the mines. ('Dig.', 47, tit. 20; Hellfeld, 'Jurispr. For.', s. 2067.) The term stellionate is used in the law of Scotland in nearly the same sense as in the Roman law. (Ersk., 'Inst.', 4, tit. 4, s. 79.)

STENCILLING is a mode of transferring a coloured pattern or design to the surface of cloth, paper, or other material. The pattern is cut through a stencil plate, usually a piece of sheet metal; and liquid or pasty colour is brushed over the plate, in such a way as to pass through the perforations, but not to reach those parts of the paper or cloth on which the uncut portions of the plate rest. Examples of the process will be found noticed under CARD-MAKING and PAPER-HANGINGS.

STENOGRAPHY, or the art of short-writing, is a term compounded of two Greek words, *στενός*, contracted, and *γράφειν*, to write. The invention of stenography among the Greeks is generally assigned to Xenophon the historian; but it is said that the art was first practised by Pythagoras, and that the poet Ennius was the first who adopted a system of short writing by which a person was enabled to follow a speaker. It is said, though upon no very certain testimony, that he commenced by employing eleven hundred marks of his own invention, and increased the number as circumstances required.

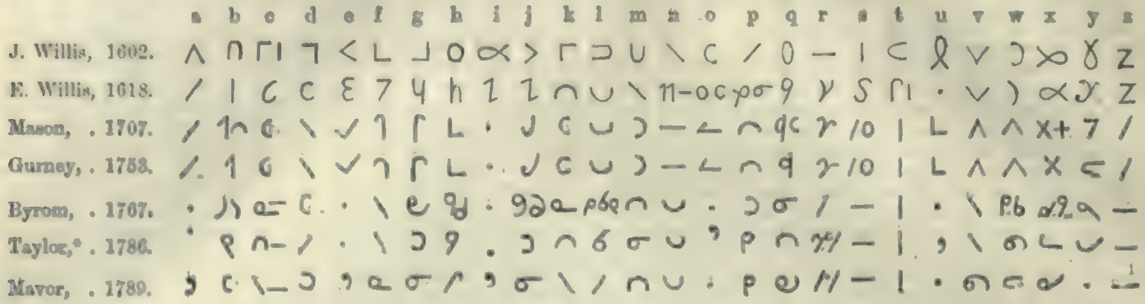
There are also writers who ascribe the invention of the art to Cicero; and it was certainly practised by him on account both of its brevity and secresy. He reminds ('Ad. Att.,' xiii. 32) his friend Atticus that he wrote (*διὰ σημείων*) by signs. The art was communicated by Cicero to Tiro, his freedman, who made considerable improvements in it, and is said to have been likewise the first person who applied it to the purpose of taking down public speeches. Eusebius attributes the invention to Tiro. The oration of Cato relative to the Catilinarian conspiracy was preserved by means of shorthand. The art was subsequently improved, and stenography became a fashionable accomplishment with the Romans. There is extant a work on the shorthand (*notæ* of the Romans) attributed to Tiro and Seneca, and printed in Gruter's 'Collection of Inscriptions.' Most of the writers of that age allude to the stenographic art in their works. Horace points out its brevity; and Ovid mentions its advantages in point of secresy. It is also commended by Ausonius, Martial, Manilius, and others. [NOTARY.] The Roman shorthand was very different from our own: the abbreviations, in general, appear to have resembled those adopted in ordinary writing, and which frequently occur in ancient manuscripts, as well as in early editions of Latin works. A very large collection of manuscript abbreviations is printed at the end of Göschen's edition of Gaius; and specimens of ancient Roman stenography are given in Lewis's 'Historical Account of Shorthand.' Some passages in the Roman writers, which have been supposed to refer to shorthand, appear to refer to writing in cipher.

The first English treatise on Stenography was published in 1588, by Dr. Timothy Bright, and dedicated to Queen Elizabeth. It was entitled 'Characterie, or the Art of Short, Swift, and Secret Writing;' and consisted exclusively of arbitrary characters, each of which represented a word. Two years afterwards appeared 'The Writing Schoolmaster,' in three parts, by Peter Bale. The system of Bale, like that of his predecessor Bright, was formed of arbitrary characters, instead of a combination of elementary marks or signs. Both systems were exceedingly crude, and difficult of attainment; requiring, as they did, for their practical application, a remarkable tenacity of memory; but they displayed great ingenuity as first attempts. The earliest effort to form a regular shorthand alphabet appears to have been made by John Willis, who in 1602 published 'The Art of Stenographie, or Short Writing, by Spelling Characterie.' The work went through numerous editions. The alphabet was formed of the most difficult and complex characters, which were ill adapted for joining, their formation consuming treble the time required for forming the characters in any of the modern systems of moderate celebrity. Willis was followed by a host of imitators, none of whom, however, effected any material improvement. In 1618 appeared a treatise upon Stenography by Edmond Willis, which was followed in 1630 by that of Witt; in 1633 by that of Dix; and by a great number of others at short intervals. That of Rich, published in 1654, was praised by Locke. In 1753 was published the system of Mr. Thomas Gurney, which has since been so very extensively practised by various members of his family and others, in the houses of parliament, the courts of law, &c.

Among the more recent systems, that of Dr. Byrom deservedly occupies a very prominent position. He succeeded in forming an alphabet at once simple, precise, and practicable, as well as in rendering the general details of his theory exceedingly clear and intelligible. His system was incomparably superior to any which had preceded it. Although the treatise was completed by the year 1720, it was not published till 1767, after the death of the author, who, as he depended for support principally upon private tuition, obtained an act of parliament for the security of his invention. The doctor, in 1749, printed fifty copies of his work for the use of his particular friends. Since its publication it has been edited by several persons. Mr. Thomas Molineux, of Macclesfield, published an edition which he entitled 'An Introduction to Mr. Byrom's Universal English Shorthand,' which was popular for many years; and some years later, Mr. William Gawtress, of Leeds, published a 'Practical Introduction to Shorthand' upon the general principles of Byrom, which is one of the cheapest and most useful manuals of shorthand which ever appeared.

The system next deserving of notice is that of Taylor, which made its appearance in 1786, and is entitled 'An Essay intended to establish a standard for a universal System of Stenography or Shorthand Writing.' This author's system is superior to that of Byrom in several particulars; but principally in a greater brevity and simplicity of the alphabet, and the facility with which the various characters may be joined to each other; all points of the utmost value and importance. Some useful practical improvements upon Taylor's system have been made in Mr. Harding's treatise on the art. Dr. Mavor's system, though it obtained considerable popularity, is inferior to that of Taylor, on account of his alphabet requiring a greater number of strokes of the pen, and the characters being more difficult of junction. Since the publication of Dr. Mavor's treatise, many others of various degrees of excellence have been published, but it is needless to enumerate them; those who desire further information as to the history of the art will find much valuable matter in Mr. Lewis's 'Historical Account of Shorthand.' The alphabets on the next page will in some measure illustrate a portion of the foregoing remarks as to the improvements which have from time to time taken place.

To shorthand writers we owe full reports of the proceedings of parliament, of public meetings, and of the courts of law. The newspaper press has indeed given a powerful stimulus to the cultivation of the art, by affording a respectable livelihood to a numerous body of individuals. In addition to what it has done for the daily and weekly press in particular, shorthand is used for taking down sermons, scientific lectures, &c. By students of divinity, medicine, law, or others, who may wish to preserve the whole or parts of discourses or lectures on scientific or other subjects, shorthand may be studied with great advantage. The art, however, is not to be acquired without the diligent application of many months, and it also requires considerable manual dexterity, though worthless treatises and travelling teachers of stenography occasionally assert the contrary.


a b c d e f g h i j k l m n o p q r s t u v w x y z
J. Willis, 1602.
E. Willis, 1618.
Mason, . 1707.
Gurney, . 1753.
Byrom, . 1767.
Taylor,* . 1786.
Mavor, . 1789.

We shall now give a brief summary of the principles of stenography, according to the system of Taylor, as improved by Harding.

Of the Alphabet.—The vowels are represented by points, a period standing for *a*, *e*, and *i*, and a comma for *o* and *u*. The single consonants of the shorthand alphabet amount only to sixteen, *c* and *z* being rejected as unnecessary, the former having both a hard and a soft sound, similar to *k* and *s*, as in the words "command" and "sentence;" *s* is therefore always substituted for *c*, where the letter has a soft sound, and *k* where it has a hard sound: *f* and *v*, being similar in sound, are both represented by the same character. For the same reason, *g* and *j* are represented by one character, as are also *k* and *q*. Characters are also assigned to double consonants, such as *ch*, *sh*, and *th*. These double consonants conduce to both perspicuity and expedition. The vowels are distinguished from each other by their position. For instance, should the period be placed over the top of a consonant, it signifies *a;* if placed against the side, or opposite the centre of the consonant, it becomes *e;* if placed at the bottom *i*. The personal pronoun *I* is represented by a mark similar to the top part of a note of admiration. The comma is *o* when placed in the same situation as the dot or period for *a*, and *u* when in the same situation as the dot for *e*. Where vowels have been generally omitted, either through the haste of transcribing remarks on any subject, or for expedition in following a speaker, they ought, where such a course is rendered necessary, to be supplied immediately afterwards, while the subject written is fresh in the recollection of the writer. In all words which have neither incipient, terminative, nor long vowels, no middle vowel should be expressed unless some peculiarity may render it expedient or necessary to deviate from this general rule. A word of more than one syllable, having a long vowel in it, must generally have that vowel expressed, because the long vowel being found in that syllable which is most distinctly heard in pronunciation, affords the greatest help in reading; at the same time, however, when a word of more than one syllable consists of several consonants, even the long vowel may be frequently omitted. The various characters of the alphabet represent, when placed by themselves, a number of small words. For example, the *a* or *an* is written by dot; *the* and also *and* by a comma, the former being written above the line, and the latter below. The consonant b represents the word *be, by, been;* d, *do, did, done;* f, *off, of; if;* g, *God, give, go, good;* h, *have, he;* k, *know, known;* l, *Lord, all, will*, and so on throughout the alphabet. For the attainment of practical proficiency in the art, it is necessary that the alphabet should be acquired so perfectly as to be written correctly four times in a minute. It is necessary also in this place to explain that *d* and *r*, which in the alphabet appear to be precisely the same in form, are distinguished by the former, when joined to another consonant, being written downwards, and the latter upwards.

Of Prepositions and Terminations.—Prepositions and terminations are the letters or signs by which the first and last syllables of words are represented. The whole of the single and double consonants of the alphabet are employed in denoting the beginnings or endings of words; in which situations the letters are not joined to the other part of the word, but placed so close as to show their connection and prevent their being mistaken for separate and independent words. The letter *b* represents the prepositions *abs, obs, &c.;* and the terminations *ble, ible, bly;* the letter *d*, the prepositions *de* and *des*, and the terminations *dom, end, ened*, &c.; the letter *f*, the preposition *for* and the termination *ful;* and the other alphabetical characters are appropriated in a similar manner. Besides the consonants several arbitrary marks are also used to denote the endings of words. In many cases a preposition and a termination together are all that are necessary to represent a word.

Of Arbitraries.—In the system of Taylor very few arbitraries are employed. They do not exceed twenty in number and may generally be employed with advantage, which is more than can be said of the arbitraries of several other systems. The experienced shorthand writer may readily, and with much benefit to himself, increase the number of these marks as occasion may require. For instance, the individual who acquires the art of writing shorthand for the purpose of its practical application in a court of law, may readily assign arbitrary marks for such technical terms or lengthy words as are of most frequent recurrence. In the same manner the student of medicine or divinity may also form such characters to suit his own peculiar pursuit; and those persons who practise shorthand for a variety of purposes may in like manner adapt them to the several subjects on which they may have occasion to take notes. The great capabilities of arbitrary characters in these respects have not, we believe, been pointed out as they might have been, either by Mr. Harding or any other author into whose system we have looked.

Of the mode of Spelling.—The great aim of shorthand being to represent words by the fewest simple characters possible, all letters which are not distinctly sounded in any word must be omitted, except in cases where their retention may seem necessary. If words are written as they are pronounced, every silent letter will of course be omitted. In following a speaker, however, it is necessary that all vowels should be omitted, or otherwise it will be impossible to take more than the substance of his remarks. Where, however, proper names occur, they should either have the vowels inserted or be written in longhand: the latter method is most advantageous, as the names, when so written, serve as rallying-points to the eye in deciphering shorthand notes. Where the vowels are omitted in general writing, the rule is to write such of the consonants as are sounded in the pronunciation of any word.

Of Miscellaneous Modes of Abbreviation.—As in following a speaker all the vowels require to be omitted, and the consonants only written, so all the small words in a sentence are likewise left out. In some cases, however, where the speaker is deliberate and the writer is expert, nearly all the words may be expressed. In the abridgement of sentences of course the writer is guided by his own judgment and the necessities of the case. The different tenses and moods of the verbs are generally expressed in the English language by the help of other verbs, as *shall, have, had, can, could, may, must, be*, &c. These being written by their first consonant, may be joined together; but a point should be inserted over the characters, to signify that they are the first letters of words in the sentence. The radical part of a word too may often be sufficient to denote the whole word, as *exp.* for expenses, *pos.* for possible, and so forth. A mode of contraction much used in common writing is to express the first and last consonants of a word, inserting a dash in the middle to show that it is deficient. This plan may be adopted in shorthand writing, or the common letters may be occasionally used. If the characters cannot be distinguished by the plan first pointed out, the termination may be written under the first consonant. The usual abbreviations in longhand can be adopted in shorthand. If a part of a sentence is to be repeated, a line may be drawn under it, and a caret placed where the repetition should be read.

As our object is not to supply a manual by which the art of shorthand may be acquired, but rather to afford some information concerning its leading principles, we have omitted explanations of minor importance.

STEPPES. [Plains.]

STEREOGRAPHIC. This word, which is derived from *στερεός*, "solid," and *γράφειν*, "to draw," and which therefore ought to be applied to every method of representing a solid in a plane, has nevertheless a limited technical sense, being applied to that projection of a sphere in which the eye is at a point in the sphere, and the plane of projection is the great circle of which the eye is at the pole, or a plane parallel to it. This mode of projection was known to Hipparchus, and was first described in the work on the planisphere attributed to Ptolemy.

The stereographic projection has two remarkable properties. The first is, that all circles are projected either into straight lines or circles. Those which pass through the eye are of course projected into straight lines; in every other case the projection is the Subcontrary section of a cone, which has its vertex at the eye, and the circle to be projected for its base; consequently the projection is a circle. As much of the circle as lies below the plane of projection (the eye being considered as above it) is projected inside the great circle on which projection is made; and all the rest outside: when this projection is employed in maps, it is usual to place all the part of the globe to be projected below the plane of projection.

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* As improved by Harding in the positions of the vowels.

The second property is, that the angle made by two circles which meet on the globe, is equal to the angle made, at the point of meeting, by the two circles which are the projections of those circles, the angle made by two intersecting circles being always that made by their tangents. This property is easily proved as follows: Draw through the point of intersection of the two circles (A and B) which are to be projected, two other circles (A′ and B′), which have the same tangents, and pass through the eye. Then the tangents of A′ and B′ at the eye make the same angle as those at the other point of intersection, that is, as the tangents of A and B at the point to be projected. But these tangents of A′ and B′ at the eye are parallel to the *projections* of the tangents of A and B at the point to be projected: whence the projections of these tangents of A and B make the same angle as the tangents themselves.

The first property was known to Hipparchus and Ptolemy: the history of the second is rather curious. The first writer who seems to have looked attentively for a discoverer was Delambre ('Mém. Inst.', vol. v., p. 393), who could not find it in Clavius, Stoffler, nor in any of the writers of the middle ages, who have treated pretty voluminously on the astrolabe, which word, as used by them, merely meant a stereographic projection. That it was mentioned (without demonstration) in the French Mathematical Dictionary of Savérien (1753), in an article which was copied word for word into the 'Encyclopédie,' was all that Delambre could then say of its origin. He afterwards, in writing his 'History of Astronomy in the Middle Ages,' found the proposition demonstrated in the 'Compleat System of Astronomy,' by Charles Leadbetter, London, 1728; but, judging from the rest of the work, he presumes that Leadbetter could not have been the discoverer. No claim was, however, at the time put in for any one else, and Savérien's article, which appeared in the 'Encyclopédie,' first called general attention to the property, and this can be traced to Leadbetter's work nearly. For we find that Savérien translated his article, word for word, from the second edition (1743) of Stone's 'Mathematical Dictionary.' Stone was a contemporary of Leadbetter, and several times refers to his writings.

On consulting the third edition of Dr. Harris's 'Lexicon Technicum' (1716), and feeling sure, with regard to that work, that such a proposition as the one called Leadbetter's would be stated, if it were then known, we turned to the article 'Spherick Geometry,' and there we found it, with a demonstration, enunciated as follows:—"All Angles made by Circles on the Superficies of the Sphere are equal to those made by their Representatives on the Plane of the Projection." The claim of Leadbetter is therefore overthrown. In the preface, Harris says that under (among others) 'Spherical Geometry' will be found entire treatises, which, if he mistakes not, are as short and plain as any extant. If this proposition had been new, he would probably have noted it here, particularly if it had been his own. We find however, finally, that the property has been shown ('Encyc. Brit.', 'Projection') to have been demonstrated by Halley in No. 219 of the 'Philosophical Transactions,' and is attributed by him to De Moivre or Hook.

The consequence of this theorem is, that any small portion of the sphere is projected into a figure very nearly similar to itself, so that any not very large portion of the earth preserves its figure with tolerable accuracy in the map. Hence some writers have said that there is no distortion in the stereographic projection, which is not absolutely true, though nearly so of countries which bear no greater proportion to the whole earth than most of them.

The mode of laying down the stereographic projection is briefly stated, and a diagram given, in the article MAP; it will be found at greater length in the memoir of Delambre above cited, or in any good work on the construction of maps.

STEREOSCOPE, from *στερεός* (solid), and *σκοπός* (a view, or *σκοπέω*, to view), an instrument by which two pictures of any object, taken from different points of view, are seen as a single picture of that object, having the natural appearance of relief or solidity.

The theory of the stereoscope is sufficiently discussed under SIGHT. The reflecting stereoscope was first described in a paper by Professor Wheatstone, entitled 'Contributions to the Physiology of Vision: Part I. On some Remarkable and hitherto Unobserved Phenomena of Binocular Vision,' read before the Royal Society, June 21st, 1838, and printed in the 'Philosophical Transactions' a few months later. The refracting stereoscope is described by Sir David Brewster in a paper 'On the Law of Visible Position in Single and Binocular Vision, and on the Representation of Solid Figures by the Union of Dissimilar Plane Figures on the Retinæ,' which he communicated to the Royal Society of Edinburgh in January, 1843. He further explained and defended his views in subsequent papers, which, like the former, appeared in the 'Edinburgh Transactions' of that and following years. The opinions of Sir David Brewster are further set forth in his work 'The Stereoscope' (8vo, 1856); those of Mr. Wheatstone must be sought in the paper already referred to, and in another which formed the Bakerian Lecture of the Royal Society for 1852, being 'Part II. of Contributions to the Physiology of Vision, and on Binocular Vision.'

The dissimilarity of the pictures, as seen by each eye separately, does not appear to be a modern discovery. It was recognised by Euclid 2000 years ago, and minutely described by Galen. The idea was revived by Baptista Porta in 1593; also by Leonardo da Vinci; by Aguilonius, in a work on the vision of solids (1613); by Harris, in 1775; by Dr. Smith, Dr. Porterfield, and others. Thus, as Brewster remarks, writers in every age knew the two facts that the pictures on the retinæ of the two eyes were dissimilar, and that by the union of these two flat distinct pictures we obtain the vision of solids. But in order to obtain accurate pictures of objects as seen by each eye, and the method of uniting them, photography and the binocular camera were required. The first was already sufficiently advanced, and the latter was introduced by Brewster; while, in order to view the pictures with effect, the lenticular stereoscope was contrived. The first instrument of this kind was constructed by the late Andrew Ross for the inventor, and was exhibited to the British Association in Birmingham in 1849. It did not, however, attract attention until the French optician Du Boscq showed his remarkable collection of stereoscopic views in the Great Exhibition of 1851, after which the demand for the stereoscope warmed into a passion which has scarcely since cooled down. The lenticular stereoscope, as described by the inventor, "consists of a pyramidal box of wood or metal, or any other opaque material, blackened on the inside, and having a lid for the admission of light when the pictures are opaque. The box is open below, in order to let the light pass through the pictures when they are transparent. Another lid is sometimes added, so as to open externally on the bottom of the box, for the purpose of exhibiting dissolving views in the stereoscope. The bottom of the box is generally covered with ground-glass, the surface of which ought to be very fine, or very fine-grained paper may be used. The top of the box consists of two portions, in one of which is the right eye-tube, containing a semi-lens, or quarter-lens, and in the other the left eye-tube, also containing a semi-lens or quarter-lens. These two portions may be advantageously made to approach or recede, in order to suit eyes at different distances from one another; and the tubes containing the lenses should draw out, in order to suit long- and short-sighted eyes." The two dissimilar pictures (which, for convenience, are mounted on a thick card, forming the universally known "slide") are placed in a groove in the bottom of the box, when, on looking through the eye-tubes, they are seen united into a single picture, and the object or objects, if a proper amount of light is obtained, stand out with an almost magical appearance of relief and solidity. For opaque slides, a mirror may be used, and made to move on a hinge, so as to throw light into the instrument. The employment of photography for the stereographs has wonderfully extended the range of the instrument.

The quarter- or semi-lens may also be used in the binocular camera. And here we may state the advantage of dividing the lenses. Whole lenses were originally used; but as the outer half of each lens is useless, as the eyes only look through the inner halves; moreover, as it is impossible to give two lenses precisely the same focal length and magnifying power, it was found to be more accurate, and even cheaper, to cut each lens into halves or quarters, and to shape each half or quarter into a round disc, with the thin part of each turned inwards in the instrument. In this way a single lens could be made into one semi-lens or two quarter-lens stereoscopes. It is evident that these portions, cut from the same lens, must have the same focal length and magnifying power. It is by means of these semi- or quarter-lenses that the stereoscopic effect is produced, though they do not themselves produce that effect. What they accomplish is the transference of the two dissimilar pictures or stereographs to a middle point. The union of these two pictures, or their superposition on that middle point, produces the stereoscopic effect. [SIGHT.] The half- or quarter-lenses are placed 2½ inches apart, corresponding to the distance between the eyes.

Among the various forms of the instrument, we may mention Smith and Beck's *achromatic* stereoscope; the *reflecting* stereoscope; Claudet's *stereomonoscope;* and Skaife's *pistolograph*, consisting of a combination of lenses of small size (one inch in diameter, and the focal length of the combination one inch). In this last instrument the thickness of the glass through which the light passes is small, and hence the actinic rays are so powerful that a photograph may be taken almost in an instant, and is not liable to the errors which the use of large lenses occasions. The small pictures, or *pistolograms*, as they are called, may be magnified by an enlarging camera. The small picture may also be inclosed between two plates of glass, and raised to a temperature sufficient to fuse the three glasses into one, effectually protecting the picture from the presence of the air, and forming what is called a *chromo-crystal*.

From what has been said, it will be gathered that the truthfulness of the stereoscopic picture must depend mainly on the character of the dissimilar pictures or stereographs. Stereographic portraits are usually taken with cameras contrived for the purpose. In order to take stereographs of landscapes, buildings, statuary, &c., the ordinary landscape camera is employed; the camera being removed, after the first picture is taken, to a position parallel to that just occupied, and at an equal distance from the principal object, but more or less distant from the first position in proportion to the distance from the object to be represented. The stereoscopic angle, as it is called, has been laid down at 1 in 25 for objects 50 feet or more distant; some have even recommended that the camera should be removed to a distance of 4 feet in order to take views of an object only 20 feet distance. But the effect of such an arrangement is obviously to make one picture represent much more of the right side, the other more of the left side, of an object falling within the field of vision, than could be seen by a person standing, say midway, between the two positions. And the two pictures so taken must, when united in the stereoscope, present an exaggerated and therefore untrue representation. In fact there will be, what is so commonly seen in the stereoscope, an unnatural appearance of separation between the chief object and the accessories. You see round the figure in fact, just as in life you see round a statuette or small model; and hence there arises that detached model-like appearance which is often, and very properly, objected to in stereoscopic representations. What the stereoscope ought to show is, the representation of an object or objects in nearly the same relative solidity, relief, and separation as the reality possesses; and that is what the stereoscope would exhibit if the stereographs were taken, as they ought to be, and as the most successful (though not the most popular) are taken, from positions little, if at all, exceeding that of the eyes apart. The great importance of strict accuracy in views of countries beyond the reach of the ordinary traveller, of antiquities, objects of special scientific and archæological interest, &c., will be at once acknowledged; and the value of the stereoscope for affording such representations in their greatest attainable perfection is daily becoming more apparent.

STEREOTYPING. [PRINTING.]

STERLING, a word applied to all lawful money of Great Britain. In Ruding's work on 'Coinage,' vol. i., p. 13, 4to. edit., the various supposed derivations of the word are given. Ruding says, "its origin and derivation are still unsettled;" but he inclines to attribute it to an abbreviation of Esterlings, people of the north-east of Europe, some of whom were employed in the 12th century in regulating the coinage of England. But, looking at the facts that *sterling* meant a *penny*, not a species of coinage; that it was used in Germany, and in Scotland before Eastern coiners were employed in England; that it is spelt *starling* by some, as by Spelman, and *estellin* by some of the French writers, we reject the derivation above, and agree with Polydore Vergil and Bishop Nicolson in deriving the name from the *little stars*, which were very common on the penny coins. (See the *Companion to the Almanac* for 1856.)

STERLING'S RULES (or Simpson's Rules). Useful formulæ used principally in estimating the "displacement" of a ship when afloat. They are derived from the equation to the parabola, and have been already noticed under SHIP.

STERN. [SHIP.]

STERNUTORIES, called also Ptarmics, agents which cause sneezing. The most familiar are snuffs of different kinds, many of which cause likewise a flow of the natural secretion from the nose, when they are termed errhines. [ERRHINES.] Sternutories are chiefly employed to occasion a violent succussion of the frame, either to restore suspended respiration, as in some cases of fainting, or to dislodge some foreign body from the nasal passage or windpipe, or more rarely to cause the bursting of abscesses in the tonsils. They are also used to avert impending fits of hysteria or epilepsy, or to terminate prolonged hiccup. Their use requires caution in individuals disposed to apoplexy or affected with rupture. They are generally improper for pregnant women and young children. They occasionally excite too violent and continued sneezing, which may be controlled by creasote; breathing diluted carbonic acid; putting a sinapism round the throat; or inhaling chloroform.

STETHOSCOPE. [AUSCULTATION.]

STEWARD, LORD HIGH, OF ENGLAND; one of the ancient great officers of state. Under the Norman kings and the early kings of the Plantagenet line it seems to have been an hereditary office. Hugh Grentmesnil held the office in the reign of Henry II., and it passed with his daughter and co-heir in marriage to Robert de Bellomont, who was Earl of Leicester. Robert's son held it, on whose death without issue it passed to the husband of his sister, the elder Simon de Montfort, who had also the dignity of Earl of Leicester. From him it passed to his son, the second Simon de Montfort, who was slain at the battle of Evesham in 1265. This high dignity then reverted to the crown, but was immediately granted to Edmund, king Henry the Third's younger son, together with Montfort's earldom of Leicester, in whose descendants, the earls of Lancaster and Leicester, it continued, and in the person of Henry the Fourth, who was duke of Lancaster, was absorbed into the regal dignity.

From this time no person has been invested with this high dignity as an heritable possession, or even for his own life, or *quamdiu se bene gesserit*; but only for some special occasion, the office to cease when the business which required it was ended; and this occasion has usually been when a person was to be tried before the House of Peers. Before this court a peer may be impeached for treason, felony, misprision of treason, and misprision of felony; but a commoner only for high misdemeanors, and not for any capital offence. The lords are summoned to appear, and the decision is by a majority, but no conviction can take place unless the majority consist of twelve or more. The spiritual lords may be present at the trial, but cannot vote. On such occasions there is a lord high steward created, who presides, and when the proceedings are closed, breaks his wand, and dissolves the court; but if the trial take place during the session of parliament, though a lord steward is appointed, it is not considered as his court, he having none of the functions of the judge, only voting with the rest as a peer, although he presides.

STIBDIAMYL. [ORGANOMETALLIC BODIES.]

STIBETHYL. [ORGANOMETALLIC BODIES.]

STIBMETHYL. [ORGANOMETALLIC BODIES.]

STIBTRIAMYL. [ORGANOMETALLIC BODIES.]

STILBENE. ($C_{28}H_{12}$) A crystalline hydrocarbon produced by the distillation of the hydride of sulphobenzoyl. *Thionessale* ($C_{28}H_{10}S_2$), another white crystalline body, is also produced at the same time.

STILBESOUS ACID. A product not fully investigated, obtained by the action of chlorine upon essence of bitter almonds.

STILBIC ACID. [STILBYL.]

STILBYL. ($C_{28}H_{11}O_4$). The hypothetical radical of a small group of organic compounds of which the following are the names and formulæ :—

Benzöin or hydride of stilbyl	$\left.\begin{matrix}C_{28}H_{11}O_4\\H\end{matrix}\right\}$
Benzile	$C_{28}H_{10}O_4$
Benzilic acid, stilbylic acid, or stilbic acid .	$\left.\begin{matrix}C_{28}H_{11}O_4\\H\end{matrix}\right\}O_2$
Chloride of stilbyl	$\left.\begin{matrix}C_{28}H_{11}O_4\\Cl\end{matrix}\right\}$

STILBYLIC ACID. [STILBYL.]

STILL. [DISTILLATION.]

STILLISTEARIC ACID. A crystalline organic acid obtained by the saponification of the vegetable fat expressed from the fruit of the *Stillingia sebifera*.

STIMULANTS or *Excitants* (in medicine), agents which increase vital action, first in the part to which they are applied, then of the system generally, and perhaps ultimately of some particular organ; and when this organ is a gland or secreting organ, a renewed or augmented secretion is observed. The nervous system seems to be the part which they chiefly influence, and through it the vascular, and in many cases the muscular. This is well seen in the simple effect following the employment of ammonia in a fainting fit, where the application of the vapour of ammonia, or its carbonate (smelling salts) to the nostrils, stimulates the brain, and so restores the heart's action, by which the circulation is resumed, and all parts dependent on it vivified. Aromatic vinegar, electricity, galvanism, and the sudden application of cold, especially alternated with heat, and chloric ether, have a like effect.

The agents which constitute this class, though often confounded with others, are perfectly distinct; differing from all by their sensible qualities, their chemical composition, the nature of their physiological effects, and of the therapeutic indications they are calculated to fulfil. They are often confounded with tonics [ANALEPTICS], antispasmodics, and even narcotics, to all of which they have relations of affinity, but are not identical with any. In so far as they both act on the nervous system, they have most affinity with antispasmodics [ANTISPASMODICS], but differ from them inasmuch as stimulants increase the actions which are natural to the different organs of the body; while antispasmodics allay or diminish inordinate or abnormal action. Nearly the same may be said of the distinctions between them and narcotics [NARCOTICS], for though the increased action excited by an agent of this class, if extreme or long continued, is followed by a greater or less degree of collapse, still this is very different from that which follows the employment of a narcotic, which is much greater, as well as more speedy. Certain articles, such as opium and alcohol, may be made to act in either way; but while opium is not unfrequently used to stimulate, alcohol is never used medically as a narcotic, though the coma and stupor which ensue from an excessive dose of it are as profound, and often as fatal, as from an overdose of opium.

Above all, stimulants are most frequently confounded with tonics; but independently of the consideration that stimulants operate directly on the nervous system, while tonics affect the muscular and sanguiferous systems, their operation, as well as the nature of their effects, is entirely different. Stimulants render the movements generally more frequent; tonics render them stronger; stimulants too freely or too often used, exhaust the excitability; tonics, within a certain limit, maintain it. The action of the one is immediate and transient; that of the other slow, scarcely perceptible, and progressive, but permanent. This is best seen in their effects on the stomach. Tonics render the digestion more perfect; stimulants quicken it: moreover, most tonics must be themselves digested before the system can benefit by them; while stimulants display their effects as soon as they touch the lips or reach the stomach. In many fevers cinchona bark produces no abatement of the symptoms for which it is usually prescribed, as the stomach is too weak to digest it; but capsicum or cayenne pepper given along with it, so rouses the stomach that the febrifuge power of the bark is then manifested.

Stimulants are of two classes: one comprising medicinal substances; the other, warmth, cold, electricity, galvanism, and mental agents, such as music (when lively), joy, hope, &c. Many of the latter class have been already treated of [BATHING; ELECTRICITY; GAL-

VANISM]; of the others, the effects are too familiar to require notice, except to recommend the practice of encouraging the hope of a favourable issue to his complaint in the mind of a patient, in all cases not desperate, as cherishing this feeling greatly increases the chance of recovery. The former class is divided into permanent stimulants and diffusible stimulants, the effect of the permanent being slower but more lasting, that of the others quick but transient. The first are used where a considerable and enduring power is wished to be imparted to the system, as in the convalescence from acute diseases, the other where some great and impending danger is to be obviated, as in cases of fainting fits, or when sedative poisons are to be antagonised. In these latter instances, ammonia, alcohol in some form, or sulphuric ether, are commonly had recourse to. Permanent stimulants are generally volatile or essential oils, pure, or in the combinations in which they exist in roots, barks, or flowers, and are often highly aromatic; malt liquors may also be classed with permanent stimulants. The precise stage in the progress of fevers and other acute diseases, when antiphlogistic or reducing measures should be abandoned, and stimulants substituted, is the nicest point that a medical attendant is ever called upon to decide; and nothing more clearly distinguishes the judicious practitioner than his correct determination of this point. It may be safely asserted that more cases are lost by a premature use of them than by delay, as the numerous relapses in fever testify. All persons recovering from severe diseases are almost in the condition of newly born children, in whom the irritability and excitability are very great. These should not be violently acted upon, but on the contrary they should be treated with the utmost gentleness and care. Sleep is a more useful restorative than any other. Stimulants are more necessary during the night than during the day, and as more persons die during that period, the use of stimulants becomes more urgent at that time. But the best and most harmless is a very strong infusion of tea, especially green, given in small quantities, every hour or two, as the danger of the case may point out.

A useful stimulant is furnished by coca, the leaf of Erythroxylon coca (Lamarck), a shrub native of South America. Its power of enabling the Indians to sustain prolonged fatigue, either on journeys or while working in mines, has been long known. It has only lately been tried in Europe. Its utility seems manifest in cases of nervous exhaustion from over-study or long fasting. A few grains chewed, or an infusion of varying strength according to the necessity of the case, wards off fatigue and assists respiration. But too much caution cannot be observed, lest a habit should be acquired, not less pernicious than the abuse of opium or alcohol. (See Pöppig's *Travels in Peru*, an extract from which is in *Companion to Botanical Magazine* vol. i., p. 161, and with *fig.* vol. ii., p. 25; Weddell's *Voyage dans le nord de la Bolivie;* Johnston, *Chemistry of Common Life*, vol. ii., p. 137, and *The Technologist*, vol. i., p. 255.)

STIVER. [Money.]

STOCKADE, in Fortification, is the name given to a wall constructed by planting upright in the ground squared trunks of trees, or rough *piles* of timber, so as to enclose an area which is to be defended. The trunks or piles are planted close together; and at intervals of three feet from one another loopholes are cut through them, or notches a few inches long are cut down, vertically, from the top, through which the defenders may direct a fire of musketry on the assailants. An inclosure of timber so planted is sometimes called a *Palanka*, from a name which is said to have been given by the Turks, when they first entered Europe, to their field-redouts or small entrenched camps.

Stockades are still frequently constructed as temporary fortifications in countries which abound with timber, as in North America and the East Indies; and among uncivilised nations, these, and rude parapets of earth, are the only kinds of fortification which have been executed. They were also, in general, the means employed by ancient armies while besieging towns, to protect themselves or to prevent the escape of the garrison. The walls with which the Peloponnesians surrounded Platæa during the siege and the blockade of that city were stockades, consisting of palisades planted close together in a double line with a certain interval between the lines. (Thucydides, ii. 75.)

The description of the pahs, or hippahs, of New Zealand, given in the accounts of Captain Cook's voyages, would nearly serve for the stockades within which the natives of that country have on several recent occasions resisted the assault of a British force. It is stated that the works consisted of trunks of trees planted close together, with a small inclination towards the interior space; and that at intervals from one another, particularly at the angles of the works, there were scaffolds whose heights from the ground were three feet less than that of the top of the wall, so that the defenders were able to see the ground at the foot of the wall while they were concealed from the view of the enemy. In the interior there was usually a hollow place, in which the women and children, with the provisions, were deposited. The pahs are generally on the summits of heights, and they are sometimes strengthened by outworks of a similar nature. Those of most recent construction are usually so placed as to allow of a ready retreat into "the bush."

On the frontiers of the United States of North America, during a war, stockades consisting of roughly-hewn trunks of trees planted close together in upright positions and pierced with loop-holes for musketry, are very frequently constructed for the purpose of inclosing an area which is to be defended; and at each of the angles of the inclosure a sort of blockhouse, serving as a bastion to flank the stockade, is constructed with very thick logs of timber placed horizontally: these block-houses are sometimes formed with an upper story, the angles of which project over the sides of the lower one, so that by loop-holes in the projecting part of the floor a fire of musketry may be made upon the enemy when at the foot of the wall.

STOCKINGS. [Hosiery Manufacture.]

STOCKS, a term applied to the various "Funds" which constitute the national debt. Each proprietor of stock may transfer his interest to others by sale. When the transfer is effected by a broker he must be authorised by a power of attorney from his principal, the stamp-duty on which is 21*s.* 6*d.*; and the document may be so drawn as to empower him both to buy and sell stock and to receive the dividends for the person by whom he is commissioned. Few persons buy or sell stock except through the medium of a broker, but the general practice is to receive their dividends themselves. The purchaser acquires the dividend due upon the stock for the current half-year, and thus at one point there will be a sum of 29*s.* 4*d.* due on three per cent. stock, and a fortnight afterwards only 1*s.* 8*d.* On the bargain being completed, the parties repair to the Bank to transfer the stock. "For this purpose the seller makes out a note in writing, which contains the name and designation of the seller and purchaser and the sum and description of the stock to be transferred. He delivers this to the proper clerk, and then fills up a receipt, a printed form of which, with blanks, is obtained at the office. The clerk, in the mean time, examines the seller's accounts; and if he find him possessed of the stock proposed to be sold, he makes out the transfer. This is signed in the books by the seller, who delivers the receipt to the clerk; and upon the purchaser's signing his acceptance in the book, the clerk signs the receipt as witness. It is then delivered to the purchaser upon payment of the money, and thus the business is completed." (Dr. Hamilton, 'History of the National Debt.')

Bargains in stock are transacted in the Stock Exchange, in Capel-court. All the more respectable brokers are members of the Stock Exchange, into which association they are elected annually by ballot; but many of the jobbers, who are not members and carry on their transactions outside the exchange, are said to be persons of wealth. The governing body consists of a committee of twenty-four, also elected by ballot. The established rate of brokerage is one-eighth per cent. (or 2*s.* 6*d.* in the 100*l.*) upon the amount of stock transferred.

The dividends on all descriptions of stock are due half-yearly, either on the 5th of January and 5th of July, or on the 5th of April and 10th of October, and are paid about a week afterwards; and for about six weeks previously, the books at the Transfer Office being closed, transfers cannot be regularly made. The transfers on each stock are effected at other times only on certain days in the week, which may be ascertained by a reference to any almanac.

The bargains for *time* form a very important portion of the business of the Stock Exchange. They are bargains to deliver stock on a certain day at a certain price, the seller of course believing that the price will fall, and the buyer that it will rise. When the period for completing the bargain has arrived, a settlement is usually effected without any payment of stock, the losing party simply paying the difference. "These bargains are usually made for certain days fixed by a committee of the Stock Exchange, called *settling days*, of which there are about eight in the year, namely, one in each of the months of January, February, April, May, July, August, October, and November; and they are always on Tuesday, Wednesday, Thursday, or Friday, being the days on which the commissioners for the reduction of the national debt make purchases. The settling days in January and July are always the first days of the opening of the bank books for public transfer; and these days are notified at the bank, when the books are shut to prepare for the dividend. The price at which stock is sold to be transferred on the next settling day is called the price *on account*. Sometimes, instead of closing the account on the settling day, the stock is carried on to a future day on such terms as the parties agree on. This is called a *continuation*." (Dr. Hamilton.) A defaulter, in the language of the Stock Exchange, is termed a "lame duck," and his name is posted for a certain time in the great room. The sellers of time bargains are also technically called "bears," and the buyers "bulls;" the interest of the former being to beat down prices, and of the latter to raise them.

Stock of a high denomination may usually be bought cheaper than that of which the nominal interest is lower; and it is therefore the most advantageous for temporary investment. There is always a probability that the stock bearing the highest rate of interest will be reduced by the government when a favourable occasion presents itself; but the price of any one stock may be taken pretty nearly as an indication of the prices of the rest. The fluctuation in the price of stocks generally may be traced to an almost infinite variety of causes—to the abundance or scarcity of money, and the opportunities of employing it to advantage in mercantile speculations; to the rumours of a new loan, or of the imposition of a fresh tax, or even the repeal of a tax; to rumours of war; and to innumerable other circumstances relating to the trade, finance, and other domestic affairs of the country. In 1797 the Three per Cents. were reduced to the lowest point which they have ever reached (47⅞) by the success of the French armies, combined with adverse circumstances at home.

Besides the English funds, shares in many descriptions of foreign stocks, which have been created by loans raised in this country, are constantly for sale in the money-market, as are also shares in railway, canal, mining, and numerous other similar speculations.

STOCKS, in Horticulture, are young trees which are designed for the reception of the grafts or buds from other trees. The process by which a part of one tree is transferred to another is called grafting or budding [GRAFTING], and the object attained by it in gardening is the securing the continuance and multiplication of an individual plant that may possess peculiarities deemed worthy of preservation. It is by this process that the great number of varieties of cultivated fruits are preserved with remarkable integrity, and by which a constant improvement may be ensured.

Stocks are for practical purposes divided into three kinds: crab stocks, free stocks, and dwarf stocks. Crab stocks are those which are grown from the seeds of wild and ungrafted trees, as the cherry, plum, apple, &c. These stocks are commonly used where a large and hardy growth is desirable. In the selection of wild stocks, those which grow cleanest, and are freest from irregularities of the stem and defects in the bark, should be chosen. Free stocks are those which are raised from the seeds or layers of fruit and orchard trees which have been grafted. These stocks are found desirable when the object of grafting is to obtain choice varieties of apples, peaches, nectarines, apricots, or plums. Dwarf stocks are those which are raised from low-growing shrubby trees. They are used in the grafting of low-standards for small gardens, also for wall-trees, and espaliers.

Stocks are raised in nurseries from seeds, suckers, layers, and cuttings. When raised from seeds, they should be sown in the autumn, in beds of common light earth: all lateral branches should be cut off as they grow up; and, according to circumstances, they will be fit for grafting in one, two, or three years. Stocks may be used when they have attained the size of a goose-quill, up to that of a man's finger. When stocks are wanted expeditiously, they may be produced from suckers taken up and planted in the autumn, when they will be ready for use the following July or August. They are not often raised from layers and cuttings.

In the selection of stocks, not only is care required that they be of the same kind as the graft or scion, but that there is a proper relation between the rapidity of their growth according to the objects wished to be attained. When the growth of the scion is more rapid than that of the stock, it will sometimes die. This is the case with peach-trees budded on plum-stocks and pears on the hawthorn. At the same time, when trees are naturally too luxuriant in leaves and branches, they may be dwarfed in their growth and made fruitful by placing a scion from them on a stock that grows slower than themselves. In this way apples may be dwarfed by being grown on paradise, pear, or quince stocks.

It is frequently desirable to select those stocks which are hardier than the scion, for the purpose of ensuring the growth of the latter. Not that the stock has any power of communicating hardiness to the scion; but those stocks that are accustomed to colder latitudes will supply a sufficient quantity of sap, and be able to resist the influence of a decrease of bottom heat. The kind of soil in which a stock grows has also much to do with its being adapted for the growth of certain scions. Thus the crab has been found best for the apple, the wild pear for the cultivated pear, the almond for the plum, and the mahaleb for the cherry, on chalky soils. But the stock also has the power of deteriorating the fruit; the austere plum and the crab will not improve the peach or the apple of the scion which may be grafted on them. Some gardeners therefore recommend stocks of what they term an ennobling character; that is, of a species as good as that of the scions they are to bear. Apricots, currants, and gooseberries are stated to have been greatly improved by this process.

STOCKS, a wooden machine formerly much used for the punishment of disorderly persons by securing their legs. The time when they were first used in England does not appear; but in the second Statute of Labourers, 25 Edw. III., 1350, in the octave of the Purification, it is enacted that refractory artificers shall be put in the stocks by the lords, stewards, bailiffs, or constables of the towns where their offence has been committed, by three days; or sent to the next jail, there to justify themselves; and that stocks be made in every town for such occasion between that time and the feast of Pentecost. ('Rot. Parl.,' ii., 234.) In 1376 the commons prayed the king for their establishment in every village. (Ibid., 341.)

In 'King Lear,' act ii., sc. 2, Shakspere has introduced the stocks upon the stage. Farmer, commenting upon the passage, says: "It should be remembered that formerly in great houses, as still in some colleges, there were moveable stocks for the correction of the servants." The stocks are still to be seen in some country places, and are not wholly disused.

STOLE, originally a long vestment, a matron's robe, from the Latin *stola*, and that from the Greek στολή. Pitiscus, in his 'Lexicon Antiquitat. Roman.,' has a long article upon the *stola*, as worn by the ancients.

In later times stola was the term more particularly applied to a broad strip of cloth or stuff, with three crosses upon it, worn by priests of the Romish church as a sacerdotal vestment, with whom it was also called *Orarium*. "Orarium est stola," says Lyndwood, in his 'Provinciale,' "qua sacerdos in omni obsequio divino uti debet, et suo collo imponitur ut significet se jugum Domini suscepisse."

The stole or orarium, according to Palmer ('Origines Liturgicæ,' vol. ii.) has been used from the most primitive ages by the Christian clergy. It is spoken of by the first council of Braga, A.D. 563; by Isidore Hispalensis, A.D. 600; the Council of Laodicea, in Phrygia, A.D. 360; Severianus Gabalitanus, in the time of Chrysostom; and many others (see Bingham's 'Antiq.,' b. xiii., c. 8, § 2; and Gerberti, 'Liturg. Aleman.,' tom. i., p. 240); and it has been continually used by all the churches of the west and east, and by the Monophysites of Antioch and Alexandria. "The stole," says Palmer, "always called Ὠράριον by the Greeks, was fastened on one shoulder of the deacon's albe, and hung down before and behind. The priest had it over both shoulders, and the two ends of it hung down in front. The Eastern churches call the stole of the priests ἐπιτραχήλιον. Thus simply were the dresses of deacons and priests distinguished from each other in primitive times."

The pall of the metropolitans was originally only a stole wound round the neck, with the ends hanging down behind and before.

That the word 'stole,' in the sense of a sacerdotal vestment, was of early adoption into the English language, appears from the 'Saxon Chronicle' under the year 963, when Archbishop Dunstan, at the time of personally confirming King Edgar's grant of lands to the monastery of Peterborough, added that he himself gave, among other vestments, his *stol* to St. Peter.

STOMACH, DISEASES OF THE. The tissues of the stomach may be the seat of various pathological states, producing symptoms which are often referred to the general head of dyspepsia. [DYSPEPSIA.] This diseased condition is, however, but a general term for the expression of a variety of symptoms arising from the pathological conditions of the organ. The morbid states of the stomach have been recently studied with great care, by the medical men both of this country and the continent. The principal structural morbid conditions of the stomach to which attention need be drawn are: 1. Softening. 2. Degeneration. 3. Congestion. 4. Inflammation. 5. Ulceration. 6. Cancer. At the same time a variety of symptoms come on indicative of a change in the functions of the stomach, and which may occur quite independent of any of the above structural derangements. Amongst the most remarkable of these functional derangements are the following:—

1. *Vomiting*, which may come on from a disordered state of distant organs, as of the brain, liver, lung, uterus, testicle, and other parts. This symptom is produced by the reflex action of the nervous system. In the majority of instances in which vomiting occurs, it is produced by the morbid condition of some other organ. It should, therefore, always lead to the investigation of other organs, as attempts at arresting it will not be successful till the cause is removed.

2. *Deficient secretion of Gastric juice.*—Many dyspeptic symptoms are directly traceable to this cause. It is accompanied with a sense of weight and oppression at the pit of the stomach. The food remains undigested in the stomach, and frequently decomposes, giving to the breath an unpleasant smell. This state requires for its treatment the administration of stimulants of the gastric function. Hydrochloric acid increases the secretion of the gastric acid, and pepsine, the active principle of the gastric juice, has been recommended as a remedy.

3. *Fermentation of the Food.*—The food may be variously decomposed according to the state of the stomach, and sometimes one change comes on and sometimes another. Without any apparent cause in the stomach itself, a fermentation comes on in the food, attended with the development of a large quantity of carbonic acid gas, and which is also accompanied with the presence of a minute plant, first discovered by Professor Goodsir of Edinburgh, and called by him the *Sarcina Ventriculi*. This state comes on when distant organs are affected, or in a general state of the system which must be attended to for cure.

4. *Indigestion*, or any derangement of the function of digestion, dependent on morbid states of other organs, either connected with the stomach, as the salivary glands, the liver, the pancreas, or the bowels, or upon derangement of organs more distant, as the kidneys, brain, &c., or upon gluttony or drunkenness. This functional derangement is cured by the removal of the cause. [DYSPEPSIA.]

The general characters of the structural diseases of the stomach are as follows: *Softening* of the mucous membrane of the stomach may occur during life as the result of the action of the gastric acid upon the membrane, or it may occur from the same cause after death. The latter form is very frequent, and was formerly regarded as an indication of structural change during life. Softening of the stomach occurs during life in wasting diseases, in which there is a great depression of the vital powers, as in typhoid fever, cancer of the womb, peritonitis, and tubercular disease of the brain. It more frequently occurs in the latter disease among children, than in any of the diseases of adults. This disease is accompanied with great disorder of the digestive functions, pain and tenderness of the epigastrium, loss of appetite, thirst, vomiting, and nausea.

Degeneration occurs in the glandular structure of the proper mucous substances of the stomach, and is the most common of the structural diseases of the stomach. In these cases either the gastric follicles are entirely destroyed, or the cells in their interior become changed, or the tissue between the follicles is charged with fibrinous and other deposits. This state is attended with severe dyspeptic symptoms, nausea or vomiting in the morning, oppression after food, and frequently anæmia and general debility. This morbid state may prevent altogether the digestion of food in the stomach; but the digestive functions of the intestines may become more active, and the general nutrition of the body must suffer. It is not however unfrequently the case that the intestinal mucous membrane is affected in the same way as the stomach, and then the general symptoms become more severe. In the treatment of these cases the object should be to relieve the stomach of its digestive duties as far as possible. Albuminous food should be taken in small quantities and frequently. The carbonates of soda and potash may also be advantageously employed so as to facilitate the passage of the food out of the stomach before digestion commences.

Congestion of the blood-vessels of the stomach occurs as the result of any mechanical impediment which prevents the blood returning from the stomach towards the heart. It occurs in disease of the liver and spleen, and leads to the deposit of melanic matters in the mucous membrane, and to degeneration of the tissue. One of the consequences of such congestion is the effusion of blood into the stomach, and its ejection by vomiting. This disease is called *hæmatemesis.* In the treatment of this form of disease efforts must be made to remove its causes. Astringents, as sulphuric acid, tannic acid, and acetate of lead with opium may be given. Sometimes congestion of the stomach occurs as the result of the suppression of some natural discharge.

Inflammation of the stomach or gastritis is a very rare disease. It is commonly seen as the result of the introduction of poisons into the stomach, and also from the excessive use of alcoholic beverages. When it occurs it is accompanied with congestion. It is attended with vomiting, excessive thirst, and the ejection of a fluid like that found in pyrosis. [PYROSIS.] In treating this form of disease all stimulants must be avoided. Food of the mildest and most easily digested kind must be administered, and leeches may be applied to the epigastrium. Iced water and lumps of ice should also be freely given.

Ulceration of the mucous membrane of the stomach occurs both in congestion and inflammation. Ulcers may however exist without the symptoms of these diseases. The ulcer is generally solitary, deep, well-defined, of a circular or oval shape, and is about the size of a shilling. It is a dangerous condition and may end fatally by perforating the membranes of the stomach, or by producing hæmorrhage, or excessive exhaustion. Ulceration is accompanied by pain of a gnawing and burning kind a few minutes after the taking of food. There is also great tenderness over the epigastrium, and frequently pain in the back. Vomiting is also a common symptom after taking food. The treatment of cases should be more dietetical than medicinal. Food must be taken in small quantities and of the most digestible kind. Milk with preparations of wheaten flour are to be commended. Astringent medicines should be administered, and the salts of iron may be prescribed with astringents should hæmorrhage supervene.

Cancerous ulceration of the stomach is not easily distinguished from simple ulcer during life, and requires the same treatment. It is not so frequent as is sometimes supposed. Dr. Brinton states that not more than one per cent. of fatal cases of ulceration of the stomach are due to cancer. Cancerous ulceration is most frequently seated at the orifices of the stomach.

(Aitken, *Handbook of the Science and Practice of Medicine;* Chambers, *On Digestion and its Derangements;* Watson, *Lectures on the Practice of Physic;* Bennett, *On the Principles and Practice of Medicine.*)

STONE. [CALCULUS.]

STONE FOR BUILDING. There are few practical questions belonging to the building arts of more importance than those connected with the nature of the stones used in them; for not only does the character of the architecture adopted materially depend upon the facilities the stones present for artistic expression, but the durability of the buildings, and the retention of their original effect must be regulated entirely by the powers of resistance of those materials to the causes of decay which are always at work upon them. Where stone of large dimensions, and of great transverse strength, is used habitually, architecture assumes an imposing palatial effect, with a tendency to prefer the horizontal to the vertical line: where stone of small dimensions is used, vaulted construction, heavy piers, and the minute style of ornamentation (which always accompanies the use of the rendering coats, almost necessarily used on such stones,) may be as distinctly traced as the external characteristics of the architecture adopted; and the horizontal line habitually disappears in favour of the arch, or of the vertical line: where stones are easily worked, florid ornamentation is adopted; where they are hard, and comparatively unmanageable, massive, and sometimes clumsy forms are adhered to. The durability of the stones, and their capacity of supporting fine sculpture, moreover, must materially affect the decision of the architect with respect to the amount of decoration to be employed on them, and to the choice of the mode in which they are to be treated; for it must evidently be absurd to spend time and money on the decoration of materials which are susceptible of rapid or of unequal decay. The resistances of stones to crushing forces have likewise a marked influence upon the style of building they are capable of receiving; for that style is often light, or massive, in proportion to the resistance, provided always that the labour in the conversion of the stone should offer little resistance to what may be called its plastic treatment. The colour of stones has also an influence upon the æsthetical effect of a building; and it, therefore, becomes in its turn a matter of importance to the architect, both on account of the original colour, and of its possible modifications.

A good building stone must possess, then, great powers of resistance to crushing, and breaking, weights; it must be even in its grain, and able to furnish large blocks; it must not contain elements which are susceptible of decomposition by reason of the atmospheric action upon them, or of their mutual reactions upon one another; it must be non-absorbent of water, or of vapour, to a certain extent (but only to a certain extent, as will be shown in the sequel); and, as far as possible, be of a homogeneous nature. As a general rule, the denser stones are more durable than the lighter ones; but this law only holds good when their structure is of a permanent and of a crystalline nature. The stones which are of a massive character from top to bottom of the quarry-bed are usually more durable than the foliated, or fissile materials of the same description; and the crystalline stones are almost always superior to the amorphous ones, both in appearance and durability. The granites, quartz rocks, and transition marbles furnish the most lasting building stones, though even they are occasionally subject to destructive actions of peculiar natures; the sandstone conglomerates, and the sandstones partially metamorphosed by the vicinity of plutonic rocks, are usually more durable than the limestones; whilst of the latter, the stones presenting a regular crystallisation are far superior to the saccharoid marbles, or to the amorphous earthy-textured stones. The clay slates, which perhaps can hardly be considered to be building stones, present singular powers of resistance to atmospheric agents, after they have been exposed to the action of plutonic rocks; and the magnesian limestones, when selected from the crystalline varieties, are of great practical value. When stones are mainly composed of organic remains united by a more or less crystalline cement, or when they are composed of materials having different rates of expansion, there are great probabilities of the occurrence of rapid decay, and materials of this description should be avoided for external uses.

In the article ATMOSPHERIC INFLUENCE will be found a short review of the present state of our knowledge with respect to the resistance of building stones to the particular causes of decay presented by that agent. There are other causes occasionally at work, however, to which it may be advisable to call attention, for the stability of a building may often depend on their action. Thus in bridges, it is found that some stones do not satisfactorily resist exposure to tidal immersion, though they may stand, as workmen say, very well when kept constantly either wet or dry; the Portland stone is an illustration of this remark. Other stones again may stand well in fresh water, but they disintegrate in salt water; others may stand well in the atmosphere of the interior of a country, and yet yield rapidly on the sea shore, or in certain towns. Some stones resist the action of fire, such as the commonly-called fire-stones of the subcretaceous series; whilst the limestones, and the ordinary sandstones, are very injuriously affected by great heat; and are either partially calcined, or split and cracked by it in a manner to destroy their powers of cohesion. Where the stones employed are intended to receive heavy crushing loads, they must be selected from amongst the denser varieties; and the portions of the stone work of a building which might take up water by capillary action must be executed of such materials as should limit its range and its chemical effect. And here it may be as well to remark that, although in positions of this kind, the non-absorptive powers of a stone are great recommendations for its use, yet that in the plain wall spaces of the upper structures externally, and in floors and wall linings internally, there is a disadvantage in the use of the decidedly non-absorbent stones. They are in fact rapid conductors of heat, and if any moisture should exist in the atmosphere it condenses on their surfaces in a manner which is unsightly, and often injurious to the health of the inhabitants of the building wherein this phenomenon occurs. Some stones are exposed to a very disagreeable action from the efflorescence of the salts they may contain; others again part with their constituents in a manner to compromise the solidity of the mass, and even to produce injury to the materials around them, as for instance, in the case of the magnesian limestone, which under the action of London rain parts with the sulphate of magnesia in such quantities as to destroy, upon its subsequent efflorescence, the materials into which it filters. It would seem, moreover, that some of the limestones are liable to chemical changes of a peculiar nature; for the marbles, such as the Carrara marble, pass from the subcrystalline to the saccharoid state on exposure to gentle heat, or to the effects of the atmosphere; whilst on the other hand, the Portland stone, and other varieties of the carbonates of lime, which have not been affected *in situ* by plutonic agencies, harden by exposure. It may be that in the former case, the water of crystallisation evaporates; and thus allows the base to resume an amorphous character; and that in the latter, the hardening proceeds from the change in the proportions of carbonic acid present, the stones being originally protocarbonates of lime, and subsequently passing into the percarbonates. The best sandstones also harden by exposure to the weather; and it may be observed that this indurating process takes place the most rapidly when the water taken up by the sandstones may contain any lime in solution.

The resistance of building stones to physical forces depends greatly upon the homogeneous nature of their grain, and the direction of their planes of stratification and cleavage; the resistance to disintegration and decay depends also very much on the same causes, especially when the stones are employed in buildings. Thus the stones which have been produced by the deposition of diluvial, or alluvial currents, present distinct traces of bedding, in consequence of the inequalities in the transporting powers of those currents at particular periods; and if those stones should be used in such a manner as to leave the planes of bedding vertical, and parallel to the exposed face of the building, they would be exposed to exfoliation of a very dangerous character. The stones which have been produced by the deposition of substances in suspension in former oceans, such as the oolites, the chalk, and the freshwater, or marine limestones of the tertiary series, often have planes of bedding produced by the periodic abundance of the animal remains they may contain; or they may have distinct laminations in consequence of their mode of crystallisation. In either of these cases the stones would be exposed to crush with greater ease in the direction of the divisional planes, and the effects of the atmosphere would be most energetically exercised when those planes were placed in a direction to favour the absorption of moisture by capillary action, or to allow the stone to exfoliate in a direction parallel to the face. In fact, the most important rule to be observed in the practical use of stone is to place it "in the natural way of the bed," as workmen say; and though there may be some stones in which it is very difficult to distinguish the bed, and others in which there is less reason than usual for adhering to this law, yet even in them it is preferable to place the bed of the stones in its natural position.

A very elaborate report was drawn up in 1839, by a commission named for the purpose of selecting the building-stone to be employed in the Houses of Parliament; but in consequence of the marked failure of the material then selected, the recommendations of that report have lately been treated with neglect. This is unfortunate; because there is much information of value in the report, and the methods of examination it was based upon are substantially correct; and, as it now appears that the stone actually used in the Houses of Parliament, *was not the one recommended by the commissioners*, the latter ought not to be blamed for the failure which has occurred. The errors which, however, do exist in the report consist in these points:—1. The resistances to atmospheric action were appreciated by the state of the stone in certain ancient buildings, which were mostly in the neighbourhood of the quarries from whence those stones had been extracted. 2. In the attempt to judge of the durability of both new and old stones by what is known as Brard's test, or exposing them to the effects of the efflorescence of a solution of the sulphate of soda. Now it is notorious that the atmospheres of large towns contain many elements which do not exist in the atmosphere of the country, and nothing but a long exposure to the former would justify an absolute opinion as to its possible effects; even the Caen stone itself resists tolerably well in Lower Normandy, but it decays rapidly at Hâvre, and more rapidly still in London. The objections raised by the French engineers to Brard's test have already been referred to under ATMOSPHERIC INFLUENCE; and it may suffice here to observe that practically it has been shown to be of very little use as an indication of the durability of a building-stone.

Before closing these remarks, it may be as well to state that some classes of stones are known by the name of *freestone*, when they are susceptible of being worked freely by the axe, or by the mallet and chisel; the ordinary sand and lime stones are of this description, but the granites, whinstones, slates, and basalts, cannot be worked in this manner. Another technical distinction in the mode of conversion arises from the description of saw used; the softer stones are cut by the toothed saw, the harder ones are cut by the plate saw and grit. The marbles are susceptible of receiving a polish; the ordinary sand and limestones remain dull whatever labour may be expended on their faces. The stones which strike fire (or the silicious ones) are usually harder and more durable than the calcareous stones; but the labour upon them is much more expensive; and it is almost always the case that the stones which present on the surfaces of their fracture, a number of asperities and sparkling facettes are more difficultly worked than are the stones which present even, dull faces. Of materials of this description the lighter coloured ones are generally softer than the darker ones, and it may be considered a safe rule in judging of new stones, that if they absorb water easily they are not fitted to resist the action of the atmosphere. If the stones should yield a clear ringing sound, they may be considered to be of a fine uniform texture, and free from flints, earthy nodules, vents, or shakes; and if in working they should emit a sulphurous smell they would usually prove to be durable. One of the simplest and best precautions to be observed in the use of building-stones, is to quarry them some long time previously to their application, and to expose them to the weather, in order that they may lose gradually what workmen call their "quarry damp." In buildings, the denser and harder stone should be used in the lower courses, the lighter ones in the superstructure; the non-absorbent stones should be used in the ground and in plinths, cills, string courses, and weather beds of cornices, &c.; the softer and more absorbent stones may be used for plain walling.

Mr. Hodgkinson found that the resistance of stone columns to crushing weights was nearly uniform when their heights were less than 12 times the dimension of their sides; when their heights were 15 times their sides, the resistance was manifestly diminished; when their heights were 24 times their sides, the resistance diminished in the ratio of 138 to 96 nearly; when they were 30 times the side, the resistance became reduced from 138 to 75; and when they were 40 times their side, the resistance was reduced from 138 to 52. Stone columns are considered by Mr. Hodgkinson to yield first at the ends, in consequence of the tendency of rigid bodies to split into wedges, with sharp points at their apices, under the action of superincumbent weights. The weights stone-columns can bear depend at all times on their smallest section.

Mr. Adie published in the 'Transactions of the British Association for the Advancement of Science,' 1834, some interesting observations on the expansion of stone under the influence of heat. From these it would appear that within a range of 180° Fahr., the expansion of the Craigleith stone is 0·0011758 of its length, or the same as the expansion of glass, and very nearly the same as the expansion of cast-iron, as ascertained by Lavoisier. The expansion of the black Galway marble was found to be 0·00043855 of its length; that of white marble seems to have been rather less. [HEAT; RESISTANCE OF MATERIALS.]

(Consult Rondelet, *l'Art de Bâtir;* Claudel, *Formules à l'usage des Ingénieurs;* Dumanet, *Cours de Construction;* De la Beche's *Geological Observer; Report on Building Stones*, 1839; *les Annales des Mines*, and *les Annales des Ponts et Chaussées*, passim; *les Annales des Travaux Publiques de la Belgique; Transactions of the British Association; Builder* (journal), passim; *Transactions of the Society of Arts*, 1860.)

STONEWARE. [EARTHENWARE; POTTERY AND PORCELAIN.]

STONE WORKING. Under QUARRY AND QUARRYING a description is given of the mode of detaching and shaping blocks of stone at the quarries. A few lines will suffice to convey an idea of the subsequent operations.

Until within a comparatively recent period, few other tools than the saw and chisel were employed in this work; but now machinery, moved by steam-power, is extensively adopted. The working of *marble* for ornamental purposes was the chief cause of this change; seeing that the highly-wrought surfaces might suitably be produced by labour-saving expedients. The sawing by hand of blocks of stone for buildings, or slabs for pavements, is familiar to every one. The workman employs a kind of blunt knife, which is converted into a species of saw by the presence of sand and water; the action of this blade, by a process something between cutting and grinding, severs the block of stone into two. The shaping by hand of blocks of stone is equally familiar; chisels, of various shapes, urged by a mallet, do the whole work. But it is of more elaborate contrivances that we here treat.

Some of the marble-sawing machines are of the kind shown in the annexed cut. Several saws are fixed parallel in a frame, at any distance apart according to the thickness of the slab to be cut. The frame slides in vertical grooves; and it is so balanced that the saws are kept at a height corresponding to the part of the block which is being cut, and descend as the cut deepens. These so-called saws are blades of soft iron, used with sand and water; the sand being varied in quality according to the kind of stone to be cut. An apparatus is placed over the frame, whereby a little stream of sand and water is made to flow continuously into each saw-cut. Not only does the use of such a machine save much labour, it saves material also; for in hand-sawing the workmen never succeed in keeping the saw in a true plane; and, as a necessary result, great waste is occasioned in subsequent grinding. Mr. Stewart has recently invented a machine for cutting large masses of stone; a series of chisel-cutters follow each other in the same cut, and are fixed to a frame travelling on a kind of railway. The action of

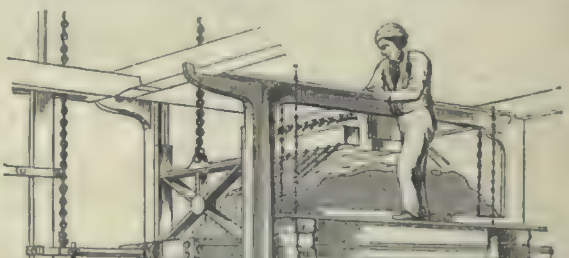


Fig. 1.—Marble Sawing Machine.

each cutter is that of a forcible blow; the machine being intended to operate upon the harder kinds of stone. Messrs. Hunter, of Manchester, have devised a machine for cutting pavement-slabs. Twenty or thirty cutters are fixed to the periphery of a revolving disc ten or twelve feet in diameter. These machines are in use in Dean Forest; some of them will cut 250 square feet of pavement, 1¾ inches thick, in ten hours.

When marble or other stone has been cut into slabs, its further working is effected by machines of various kinds. To reduce it to narrow slips, it is exposed to the action of small circular cutters, ranged parallel on one common axis; the distances between the cutters are made equal to the intended widths of the strips; the marble is slowly brought up to the revolving cutters by the action of pulleys and weights.

Circular pieces are cut from slabs by ingenious machines. Large circles are cut by means of four cutters placed at the ends of the arms of a horizontal cross; the size of the cross determines the diameter of the circle to be cut, and the curvature given to each cutter is made correspondent thereto. When the frame or cross is made to rotate, the four cutters follow one another in the same path, and speedily cut out a circular piece. Smaller circles are cut by means of a hollow cylindrical tool, something like a punch; but it acts by continual rotation, and not by blows. By a modification of this apparatus, round pillars and hollow cylinders or tubes of stone may be cut.

To produce mouldings, or similar symmetrical cuttings in stone, various machines are employed. The turning-lathe is used for circular objects. Iron cutters, with sand and water, are not used here; but the workman acts upon the stone with long, sharp-pointed instruments of steel; and when the shape has been thus roughly produced, it is finished by gouges and other tools. Strips of stone or marble, such as those used for chimney-pieces, have mouldings formed upon their surfaces by different means. The cutters here are in fact grinding tools. They consist of masses of iron, whose surfaces are circular, and have been wrought into various forms, such as hollows, beadings, ogees, &c.; the tool rotates rapidly in contact with the stone, which is brought up close to it by a weight and pulley; and thus a moulding is formed on the surface of the strip of stone, a counterpart of that on the iron tool. A workman applies sand and water to the iron tool. The apparatus is shown in the annexed cut.

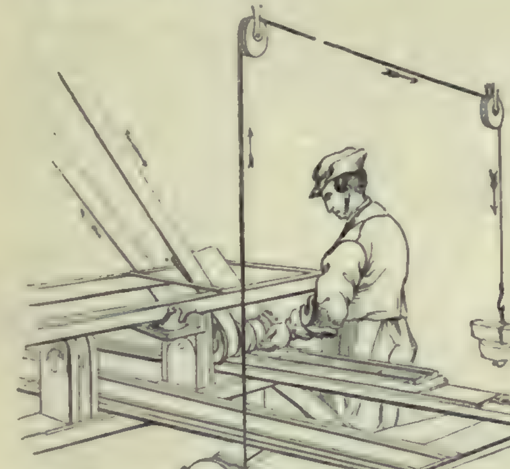


Fig. 2.—Marble Moulding Machine.

The smoothing, grinding, and polishing of marble and stone are effected by machines variously arranged. Large slabs are ground by a plate of cast-iron. The slab, placed horizontally, has a reciprocating motion given to it; the iron plate, resting upon it, has a kind of spiral motion; and the two motions together enable the iron to act equally on all parts of the stone. Sand and water are let down between the two surfaces, through holes in the iron plate. Smaller surfaces of stone or marble are ground by being held down by hand upon the surface of a revolving iron table, kept moistened with sand and water. The Earl of Caithness has recently devised a machine for dressing the surface of Caithness rag slabs, a stone well fitted for street pavements. About 30 iron bars are ranged parallel and vertical, each with jagged teeth at the bottom; a crank movement lifts them all to a certain height, one after another, and lets them fall heavily; the slab slowly moves beneath them, so as to be subjected all over to an equal amount of jagging or chipping. This produces a surface level but not smooth.

The polishing of marble requires tools different from those used in grinding or smoothing. The tools are made of lead or some other heavy substance, and are faced with a peculiar kind of felt, which, when wetted and rubbed to and fro by any convenient machinery polishes the marble. For smoothing and polishing of carved marble, or of small pieces shaped in any irregular way, small pieces of cast-iron, gritstone, smooth stone, slate, &c., are used in various ways.

STOP. [ORGAN.]

STOPPAGE IN TRANSITU is the seizure by the seller of goods sold on credit during the course of their passage (transitus) to the buyer. This principle is said to have been established about 1690 in the Court of Chancery (2 Vern., 203); and it has since been acknowledged in the courts of common law. The transitus is defined to be the passage of the goods to the place agreed upon by the buyer and seller, or the place at which they are to come into the possession of the buyer. This definition does not mean that the term transitus implies continual motion: goods are in transitu while they are at rest, if they are still on the road to the place to which they have been sent. This doctrine of stoppage in transitu entitles a seller, who is empowered to stop the goods before they come into the buyer's possession. The right is not confined to cases of buying and selling. A factor either at home or abroad, if he consigns goods to his principal by the order of the principal and has got the goods in his own name or on his own credit, has the same right of stoppage in transitu as if he were the seller of the goods. Questions of stoppage in transitu sometimes involve difficult points of law. The right of stoppage implies that the goods are in the possession of the seller or factor when he exercises this right. The exercise of the right is excluded in the case of a bill of lading which has been endorsed over; for here the endorsement passes the property in the goods absolutely to the endorsee.

STORAX. [STYRAX.]

STORMS. [TORNADO; WHIRLWIND.]

STOVE. [COOKING APPARATUS; SMOKE, CONSUMPTION OF; WARMING AND VENTILATION.]

STOVE-PLANTS. [HOTHOUSE.]

STRABISMUS. [SQUINTING.]

STRAIGHT, STRAIGHT LINE, PLANE. There is no occasion to define a straight line as matter of information; so that we have here only to consider the definitions which have been given and their relative merits, taking them as attempts to produce a mathematical description of straightness.

There are three attempts at definition of a straight line; by Plato (or one of his immediate school), by Archimedes (as is said), and by Euclid. The moderns have repeated these various forms, but have not, to our knowledge, ever succeeded in producing a definition entirely new which did not contain the defects of one or other of the three just mentioned.

The Platonic definition, according to Proclus, is as follows:—"A straight line is that of which the middle parts hide (ἐπιπροσθεῖ) the extremities;" a physical definition, owing its truth to the circumstance of the rays of light proceeding in straight lines, and involving the notion of straightness as a part of its own explanation. This definition has been little if at all used by geometrical writers.

Archimedes defines a straight line as the shortest distance between two points, or at least this definition is often attributed to him, but not correctly. It is one of his postulates in the book on the Sphere and Cylinder, that of all lines drawn between two points the least is that which is straight: but he is too well judging a geometer to assign such a property as a definition. The Arabs substituted the shortest-distance description for the definition in Euclid, and accordingly our earlier editions of Euclid do the same; nor was this flaw removed until 1505, when Zamberti translated Euclid from the Greek. It has often been supposed that this shortest-distance definition is good as a definition, though not proper for a pupil in geometry, an opinion from which we must dissent: for how is it known to those who are yet to learn what a straight line is, whether there can be a shortest distance? That is, how is it known that there are not many distances between two points, on different lines, which are severally shorter than any other distance, and equal to one another? The answer is, no doubt, that the mind has a perfect conception of the impossibility of such a thing; and the rejoinder is—yes, because the mind has a perfect conception of a straight line: that is to say, the definition is only saved from causing confusion by its own uselessness. Again, the supposition that measurement of distances on all manner of curves is to be a preliminary to one of the definitions of a science which treats no curve but the circle, and does not succeed, by reason of certain limitations of process, in measuring distance even on that one, is an incongruity.

Euclid defines a straight line to be that which lies evenly (ἐξ ἴσου κεῖται) between its extreme points. The words ἐξ ἴσου have been translated *ex æquo* by Barocius, *ex æquali* by Zamberti, *equally* by Billingsley (taking some of the oldest translations as specimens). The definition wants precision, but the meaning is obvious. Two points being given, the surrounding space may be viewed in all manner of relations to those two points, as above or below, right or left, &c. The straight line which joins the two points is that which is not more related to one of these notions than to any other; and throughout its whole length takes an even course, without a possibility of being claimed, so to speak, by any one of the surrounding parts of space rather than by any other.

In making such a definition Euclid is well aware that he cannot rest any conclusion upon it, and that in the postulate that two straight lines cannot inclose a space lies all his power of producing a theorem. Why then, it may be asked, does he introduce a definition at all? Why not give the reader to understand that a straight line is a notion universally understood and incapable of definition in simpler terms? To these questions the answer may be twofold. In the first place, he is not answerable for the genius of any language but his own, and it is very possible that to a Greek commencing geometry, εὐθεῖα might be a hard word, and ἐξ ἴσου κεῖται a real explanation; in which case his definition is defensible until it can be shown that he might have chosen a better one. We are not to judge of the force of the last-quoted words from the *ex æquo* of the middle Latin, or the *evenly* or *equally* of the English. Secondly, he is evidently, in some of the first definitions, recalling, and not instilling, notions: he is proceeding with his reader as by words to which both attach a conception, and he tries these words for use by ascertaining that both parties agree on such circumlocution as can be substituted for them.

The greatest defect of Euclid's definition, since it applies even to the view just taken of its intent, is the want of words signifying that ἐξ ἴσου refers equally to *all* adjoining parts of space: Euclid is thinking too much of a plane before he has defined a plane. Suppose, for instance, a sphere, and that lines on a sphere only are contemplated: the line which joins two points ἐξ ἴσου with reference to all adjacent parts of that sphere is not a straight line, but an arc of a great circle.

Is it possible, taking such allowances as Euclid sanctions in the use of figure, to give what shall be, whether difficult or not difficult, capable of use or not capable, a just definition of a straight line? We think it is, as follows:—The Greek geometer implicitly allows (i. 4) a TRANSLATION of figure without change of form or properties: from this, by first defining the plane, a definition of the straight line may be proposed, which we bring forward, not for any value which it has, but because the stipulations of geometry are better understood by consideration of cases proposed for acceptance or rejection, than by any other method.

1. Let two points (A and B) be said to be at the same *distance* from a third (C), when A and C being joined by *any* line, the line CA can be translated, C remaining fixed, so that A shall be brought to coincide with B.

2. A plane is a surface any point of which is equally distant from two given points.

3. A straight line is the intersection of two planes.

In the debates of the normal school, which were taken down in shorthand, and published in 1800, is a discussion on this subject. Lagrange presiding, Fourier, then one of the pupils, proposed the preceding second and third definitions, but without assigning a definition of equi-distance independently of the straight line. He also proposed as the definition of a straight line the locus of a point which is equidistant from three given points; which is faulty, inasmuch as the three given points should not be in one straight line, which cannot be supposed until the straight line is defined. Lagrange admitted the rigor of the definition, but considered that it failed in presenting a sensible image of the thing defined. Another of the pupils however insisted that the idea of distance involved that of a straight line, which is true of distance as a *quantity*, though not necessarily so of equi-distance as a *relation*.

General Thompson proposes to define a straight line as one which being turned about its extreme points suffers no change of place. Lagrange, in the debate above alluded to, suggested the same notion. This definition, we think, offers the most tangible illustration of that of Euclid. Let the two extremities of the intended straight line be situated in a solid; and let them remain fixed in space while the solid takes such motion as, under that condition, it is capable of. The straight line, the line which lies ἐξ ἴσου with regard to the extreme points, then remains fixed. For if any part of it moved, there would be in every position a relation to adjoining parts of space, which would be in a state of continual change. The connexion between this definition by rotation and that of Euclid might require more development to render it as clear as possible: but we think the student's own reflection will lead him to make it satisfactorily. But whatever may be thought of the endeavour to exercise the discrimination of which geometry points out the possibility by framing or arguing on definitions, we do not remember to have seen one so well calculated for the mere beginner as the following:—"A straight line is a straight line."

The postulates relative to a straight line demanded by Euclid (we do not speak of his translators) are: 1. That such a line can be drawn from any one point to any other. 2. That when terminated, it can be lengthened indefinitely. 3. That two such lines cannot inclose (μὴ περιέχειν) a space. It is also tacitly assumed that every part of a straight line is a straight line: that every straight line, infinitely produced, divides a plane in which it lies into two parts, and will be cut by any line drawn from a point on one side of it to a point on the other. It might also have been assumed that two straight lines which coincide in two points, coincide when produced beyond those points; but here Euclid has preferred to assume that all right angles are equal. [RIGHT ANGLE.]

The definition which Euclid gives of a plane, is that of a surface which lies evenly between its bounding straight lines. To this definition there is the serious objection that though a plane may be as easily conceived as a straight line, yet it is actually capable of definition by a straight line. For a plane is the surface any two points of which can be joined by a straight line which lies wholly on the surface. Neither this definition (nor Euclid's) precludes the necessity of a postulate demanding the possibility of drawing a plane through any straight line. Objections might be made to the first part of Euclid's eleventh book, which would require for their answer that another postulate should be granted, similar to that required for a straight line, namely, that if two planes coincide in any portion of surface, they coincide altogether. Euclid does in fact assume a postulate which is not expressly laid down, namely, that a finite straight line can be produced in every plane in which it lies, but we think it may be fairly doubted whether the first three propositions of the book in question are as perfect as they might be made.

STRAIN. [SPRAIN.]

STRAIN AND STRESS. [MATERIALS, STRENGTH OF.]

STRAMONIN. A crystalline body contained in stramonium seeds.

STRAMONIUM, botanically the *Datura Stramonium*, or *Thorn Apple*, an introduced but now frequently self-sown and consequently wild plant, found particularly wherever a garden once has been. The leaves and seeds are officinal. The leaves during drying diffuse a stupifying odour, and become deep grayish green, and then scarcely possess any odour: the taste is disagreeable, saline, and strongly bitter. The seeds are kidney-shaped, flat, about the size of linseed, uneven, nearly black: when bruised the smell is disagreeable and repulsive; taste bitterish and oily; by expression sixteen ounces of fresh seeds yield two ounces of clear fat oil, which has neither taste nor odour. The seeds of the other species of datura are often substituted, perhaps without any great disadvantage. They are also confounded with the seeds of *Nigella Sativa*, which, though black, are smaller, nearly three-cornered, and have an acrid aromatic taste, and in considerable quantity are poisonous like those of stramonium.

The seeds are used to form the extract; they, as well as the unripe capsules, yield the alkaloid called *datura*, which crystallises from its solution in alcohol or water in colourless shining aggregated prisms; without odour when pure, but when impure possessing a strongly narcotic odour; taste at first bitter, then very acrid, and like tobacco. This is extremely poisonous: one-eighth of a grain can kill a sparrow in less than three hours; and the smallest quantity applied to the eye causes very lasting dilatation of the pupil.

Stramonium in small doses causes slight convulsive action about the throat, with dryness of the tongue, disposition to vomit, and general diminution of sensibility, with slight increase of secretion of the skin, mucous membranes, and kidneys; but if the dose be larger, the brain becomes affected, and vertigo, indistinctness of vision, with dilatation of the pupil, disposition to sleep, or coma, but more frequently delirium, are added. The delirium is always peculiar, and the individual manifests a disposition to perform ridiculous actions, or assume absurd positions. If the dose be still larger, and produce fatal effects, the brain is usually found to be much congested, the vessels being gorged with blood. Large bleedings generally save the patient; emetics can rarely be made to act, as is observed when other narcotic poisons have been taken. Stramonium is most useful in cases of increased sensibility, particularly in local affections of the nerves; it is decidedly useful in allaying pain of the sciatic nerve, particularly when combined with ipecacuan. It has been recommended in mania, especially when accompanied with lucid intervals, in epilepsy, and hysteria; but with very variable success, probably to be accounted for by the careless preparation of the medicine. It is popularly used for smoking, to allay paroxysms of asthma, but its employment in this way is quite empirical, and regulated by no clear principle. By the action of heat during smoking, an empyreumatic oil is found, similar in properties to that of hyoscyamus.

STRATEGY (from the Greek *στρατηγία*, which may be translated "generalship") is, properly, the science of combining and employing the means which the different branches of the art of war afford for the purpose of forming projects of operations and of directing great military movements: it was formerly distinguished from the art of making dispositions, and of manœuvring, when in the presence of the enemy; but military writers now, in general, comprehend all these subjects under the terms of grand and elementary tactics. [TACTICS.]

The general principles of strategy and tactics have been and must be the same in all ages. To overcome the enemy, it is necessary to be superior to him at the point of collision, not necessarily numerically, for number only does not always represent the strength or relative strength of an army, but superior when due allowance is made for other advantages or disadvantages. The object then of all strategical combinations should be to bring the mass of the forces in collision with fractions of the enemy; and secondly, to act as much as possible on his communications or lines of operations without exposing one's own. The roads on which an army, or portion of an army, marches, are termed strategical lines, and the belt of ground containing two or more strategical lines, if lying close together, is termed a line of operations. In order then to bring, and always to have the power of bringing, the mass of the forces in collision with fractions of the enemy, it is necessary to choose such lines of operations as are *interior*; interior, that is, with respect to those on which the enemy acts. That is to say, that these lines must be, relatively to those of the enemy, such that the portions of the army moving on them may be more easily or rapidly united than the enemy can be, moving on his, so as to be superior at any particular point to the enemy. As a general rule, then, disregarding the relative rates of marching of armies, cross roads, &c., interior lines are such as are closer together.

Strategy consists, therefore, chiefly in making choice of convenient bases (fortified places or strong positions) in order to place there in security the military establishments of an army; such as the barracks, hospitals, and magazines of ammunition and provisions, previously to commencing offensive operations, or in contemplation of the army being compelled to act on the defensive. In the former case, it may be necessary to decide on undertaking the siege of some fortress on a frontier, should there be none such in possession, for the purpose of holding the neighbouring district in subjection, and commanding the roads by which it may be thought convenient to penetrate into the enemy's country, or by which the provisions and warlike stores may be brought up to the immediate seat of the war. In the latter case, choice is to be made of positions strong by nature, or which may be made so by art, for the army to retire to while disputing the ground gradually, harassing the enemy by frequent skirmishes, or preventing him from receiving supplies by intercepting his convoys on the roads.

Thus, after the battle of Vittoria (1813) the allied British and Spanish armies being at a great distance from the original base of operations in Portugal, and it being intended to carry the war into France, Lord Wellington undertook to besiege St. Sebastian and to blockade Pampeluna, in order, by the possession of those places, to have secure stations for his recruits and magazines while the army advanced into the mountainous districts between St. Jean Pied-de-Port and the sea. On the other hand, the conviction, in 1809, that the British army would be compelled to act entirely on the defensive, induced the English general to take measures for a retreat into Portugal, and to commence, many months before the retreat took place, two chains of strong redouts on the north of Lisbon, in the expectation of being able there to resist effectually the very superior forces of the enemy.

The project formed by Marshal Soult, in 1813, in opposition to that of Lord Wellington, affords also a good illustration of the nature of strategical operations. The French general decided to advance towards Pampeluna in the hope of being able to succour that place, and afterwards to unite his army with that of Suchet in Aragon: he expected also to command the road along the Spanish frontier, by which he might have got to the rear of the allies in a fertile country, where his army could have found subsistence. (Napier, vol. vi.) This project failing, and the battles of the Pyrenees having forced the French army to act on the defensive, Marshal Soult took measures for protracting the war to the utmost.

In the defence of an extensive territory, since it is generally impossible to cover the whole, the principles of strategy indicate that the army should be kept in force on a few of the most important positions. By securing these, the designs of the enemy may be more effectually frustrated than if it were attempted to occupy every post in the country; for the different divisions of the army being in the latter case weak and ill supported, they are liable to be cut off in detail, whereas the difficulty of dislodging a large body of troops from one strongly intrenched position may deter the enemy from attempting it: at the same time the occupation of that position by the defending army may paralyse his movements by rendering it dangerous for him to leave in his rear a force which might prevent him from drawing supplies from his magazines. The evils attending the dissemination of troops over a great extent of country are strongly exemplified in the surprise of the Austrians by Marshal Turenne. The French general caused the several corps of his army to be drawn together towards Befort in such a manner as not to excite notice; and from thence suddenly penetrating into Alsace, in the midst of the enemy's quarters, he defeated the troops before they had time to unite.

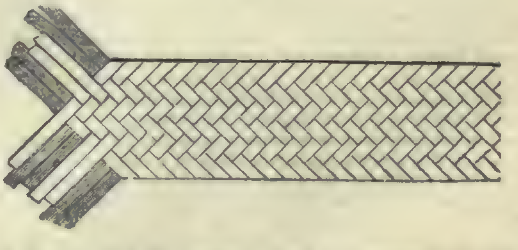
STRAW-PLAIT MANUFACTURE. The domestic character of this branch of industry, which renders it peculiarly important as a means of affording employment to women and children, especially in agricultural districts, may probably account for the circumstance that very little is known of its history. It is not known when the manufacture of hats or bonnets of plaited straw first became important in Italy, where it has long formed one of the leading pursuits of the agricultural population; but it appears from Coryat's 'Crudities,' published in 1611, that "delicate strawen hats" were worn at that time by both men and women in many places in Piedmont. Coryat states that many of these hats had at least a hundred seams, from which it is evident that very fine plait was made at that time. The straw-plait manufacture does not appear to have been followed in England for more than about a century. The wives and daughters of the farmers, before that time, used to plait straw for making their own bonnets, before straw-plaiting became established as a manufacture. Gipsy straw-hats were worn by ladies in this country about 1745-6. When Arthur Young visited Dunstable, in 1768, the straw-plait manufacture appears to have been established, though not very extensively. In Macpherson's 'Annals of Commerce,' published in 1805, Dunstable is described as "a town in the neighbourhood of which the women and children are employed in making hats, baskets, and many fancy articles, of straw, which in their hands assumes a vast variety of figures and colours, and produces considerable emolument, especially since the straw hats have been in general request among the ladies."

The large size of the wheat-straw used in this country for plaiting prevented the home manufacture from entering into competition with that of Italy in articles of fine quality; the straw grown for the purpose in Tuscany being much smaller, as well as superior in colour. This difficulty was in some degree overcome by the expedient adopted in England towards the end of the last century, of splitting the straw, and using the narrow *splints*, or slips of straw, in lieu of whole straws. The operation of splitting is performed by small cutting instruments called *machines*, which have a number of sharp edges so fixed as to divide the straw, by a motion in the direction of its length, into four, five, six, or more equal parts. Before machines were invented, straws were occasionally split with knives by hand; a process which was both tedious and unsatisfactory, since it gave no security for the uniform width of the splints, upon which the beauty of the plait greatly depends. Mr. Corston, in a letter addressed to the Society of Arts in 1810, observes that "by the mere invention of the splitting of a straw a source of employment has been discovered, which has increased the returns in that branch not less than from 300,000*l.* to 400,000*l.* annually."

Greatly as the British straw-plait manufacture had been encouraged by the use of split straw, by improvements in bleaching, and by increased care in the selection of straws of uniform size and colour, it was found, when the re-establishment of peace allowed the free importation of Italian straw hats, that the home manufacture was unable to compete with the foreign, notwithstanding the heavy protective duty levied upon hats or bonnets of straw imported from other countries. The Society of Arts therefore, for a long series of years, offered encouragement to attempts for the improvement of the British straw manufacture, which called forth many interesting communications, and has led to great improvement. As early as 1805, the Society presented a gold medal to Mr. William Corston, of Ludgate Hill, for a substitute, of his invention, for Leghorn plait. His plait was formed of rye-straw. More recently rye-straw has been tried for the same purpose by Messrs. J. & A. Muir, of Greenock, who attempted to establish the straw-plait manufacture in the Orkneys. In plait made of split straw, unless two splints are laid together, with their inside surfaces towards each other, as in the plait called "patent Dunstable," it necessarily happens that the face of the plait exhibits alternately the outer and inner surfaces of the straw, which differ from each other in colour and gloss. Articles made of split straw are also inferior to those of whole straw of equal fineness, in pliability and durability. Another circumstance which greatly increases the beauty of Leghorn plait is the mode of joining it, so as to form, by the combination of several narrow strips, an extended sheet of plaited work. British split plait is usually joined by making the several rows of plait overwrap each other a little, and then stitching through the two overwrapping pieces with a needle and thread. The surface of a hat or bonnet formed in this manner consists of a series of ridges; and part of each row of plait is concealed by that next above it, so that to form a band one inch wide, with a plait a quarter of an inch wide, it will be necessary to use *five* pieces of plait; at least a fourth part of the width of each being absorbed by the overwrapping joint. Leghorn plait is formed in such a manner that it may be joined without this loss; the edge of one row of plait being, as it were, knitted into the edge of the other, in such a way that the pattern may appear uninterrupted, and the line of junction be almost invisible.

The home manufacture of Italian straw was introduced by Mr. Parry in 1822. The ears are cut off with a knife, and the straws are then carefully sorted to obtain uniformity in length, thickness, and colour. The plait, of which an engraving is given below, consists of thirteen straws. These are tied together at one end, and then divided into two portions; six straws being turned towards the left side, and seven to the right, so that the two portions of straw may form a right angle. The seventh or outermost straw on the right-hand side is then turned down by the finger and thumb of the right hand, and brought under two straws, over two, and under two. This being done, there will be seven straws on the left and six on the right side of the angle; and the next operation is to turn down the outermost of the seven with the left-hand finger and thumb, and to pass it under two straws, over two, and under two. The right side will again have seven, and the left side six straws; and the plaiting must be continued in the same manner, alternately doubling and plaiting the outermost seventh straw

Fig. 1.



from side to side, until it becomes too short to cross over so as to double on the other side of the angle. The plaiter then takes another straw, and puts it under the short end at the point of the angle (the middle of the plait), and, by another straw coming under and over the joined one from both sides of the angle in the operation of plaiting, it will become fastened; the short end being then left out underneath the plait, and the newly fastened straw taking its place on that side of the angle to which the short one was directed. The plait thus formed is represented in the cut *fig.* 1, about double the real size. The plait is formed in pieces of great length, which are adjusted in spiral coils, with their adjacent edges knitted together, so as to form the large circular pieces of plait which, under the name of hats, or *flats*, are so extensively exported from the north of Italy. The mode of effecting the junction may be explained by the help of the annexed cuts. *Fig.* 2 represents, about four times the real size, the two adjacent edges when knitted together; the dotted lines indicating the edges of each piece of plait, and showing how far the angular folds, or *eyes*, of one piece are inserted into those of the adjoining piece. The thread by which the two rows of plait are held together is here straight, and is entirely concealed in the plait. The joint is, indeed, only to be detected on either side by the slightly increased thickness of the plait where the angles are inserted into each other, and the thickness of the thread itself. The mode of junction may perhaps be better understood from *fig.* 3, which represents the pieces of plait drawn a little asunder, and shows the course of the thread, which is indicated by dotted lines where it is covered by the straw. The operation is performed by pushing a needle through the folds in the required order, and, after passing it through as many as can be conveniently done at once, drawing it through in the manner of a bodkin, leaving its place to be taken by the thread. Sometimes, for the sake of expedition, only every alternate fold is threaded. In arranging the plait in a spiral coil, as in making a hat, it is necessary, in a few places, to force two loops of the smaller circle into one of the larger circle adjoining it, to allow for their different diameters.

Fig. 2.

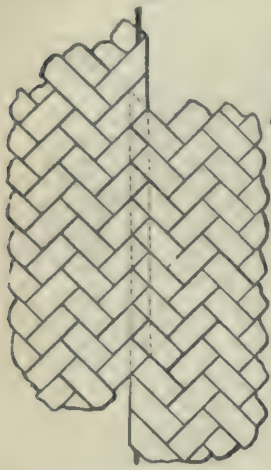
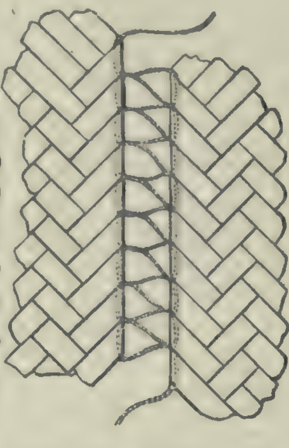


Fig. 3.



Specimens have been produced in England even finer than real Leghorn; but such extreme fineness can only be attained by a sacrifice of strength, and an increase of work.

The material commonly used for plait in Tuscany is the straw of *Triticum turgidum*, a variety of bearded wheat, which seems to differ in no respect from the spring wheat grown in the vale of Evesham and in other parts of England. It is grown in Tuscany solely for the straw, and not for the grain; and the upper joint of the straw is that chiefly used for plaiting. The straw is pulled while the ear is in a soft milky state; the corn having been sown very close, and consequently produced in a thin, short, and dwindled condition. It is then dried by spreading it thinly upon the ground in fine hot weather, and afterwards tied up in bundles and stacked, for the purpose of enabling the heat of the mow to drive off any remaining moisture. After remaining in the mow for about a month, it is spread out in a meadow and exposed to the action of dew, sun, and air, in order to bleach it. The straw is frequently turned during this operation; and after it is completed, the lower joint of the straw is pulled off, leaving the upper joint, with the ear attached to it, for use. This part is then subjected to the action of steam, and to fumigation with sulphur, in order to complete the bleaching, after which it is ready for use. It is tied up in bundles, and imported to England in this state.

Bleaching with sulphur is commonly practised in this country. The apparatus for this process usually consists of a cask open at both ends, with its seams papered. It is set upright on the ground, having a hoop nailed to it inside, about 6 inches beneath the top, to support another hoop with a net stretched across it, upon which the straw is laid loosely. The cask is then covered with a tight overlapping lid, stuffed with lists of cloth. A brazier of burning charcoal is inserted beneath the cask, and upon this is placed an iron dish containing pieces of brimstone. The brimstone soon takes fire, and the sulphurous acid gas evolved during its combustion fills the cask, and bleaches the straw in three or four hours. After bleaching, the straw is aired and softened by spreading it upon grass for a night, and it is then ready for splitting. Chloride of lime is also employed as a bleacher.

Straw may be dyed, for ornamental purposes, of many different colours. Blue is given by a boiling hot solution of indigo in sulphuric acid; yellow, by decoction of turmeric; red, by boiling hanks of coarse scarlet wool in a bath of weak alum-water containing the straw; or directly, by cochineal, salt of tin, and tartar. Brazil wood and orchil are also employed for dyeing straw.

The *splints*, or pieces of split straw, being curved in a way which would impede the operation of plaiting, require to be flattened between rollers. These, as well as the whole straws used in other kinds of plait, are moistened with water to render them easy to work. It need hardly be observed that cleanliness is indispensable to the beauty of the plait. Hence the Italian plaiters find the spring to be the most favourable season for the work, as the plait is not then exposed to the smoky atmosphere of the huts as in winter, nor to the dust and perspiration of summer. The Italian plait is dressed and polished by passing it forcibly between the hand and a sharp piece of wood.

The British straw-plait district comprises Bedfordshire, Hertfordshire, and Buckinghamshire; those counties being the most favourable for the production of the wheat-straw commonly used for English plait. The manufacture is also followed in a few places in Essex and Suffolk; but very little in other counties. The principal markets are Luton, Dunstable, and St. Alban's. In Italy the manufacture is chiefly followed in the neighbourhood of Florence, Pisa, Siena, and the Val d'Arno, in Tuscany; and it is also established in Venice and other places. There, as in England, the manufacture is purely domestic. The chief market is Florence; and the demand is principally from England, France, Germany, and America.

There are many kinds of straw-plait made in England, known by the names of *whole Dunstable, patent Dunstable, split straw, Devonshire, Luton, Bedford, Leghorn, Italian, backbone, lustre, wave, diamond, &c.*,—differing one from another in the straws being whole or split, in the thickness of the straws, in their number, or in other particulars. There has also, within the last few years, been a great extension given to the trade, by the combination of lace, whalebone, mohair, and other substances with the straw, leading to the production of very beautiful fabrics.

In the 'Companion to the Almanac' for 1861, is an article by Mr. Charles Knight, describing many of the features in the English straw-plait manufacture of the present day. A few of the chief facts will here be given in a condensed form. The census of 1851 showed that 28,000 females of all ages were engaged in Great Britain in this manufacture; of whom 10,000 were in Bedfordshire, 9000 in Hertfordshire, 3000 in Buckinghamshire, and the rest scattered in other counties. When seasons are favourable, and fashion tends to the wearing of straw hats and bonnets, many girls and women turn their attention to this trade, who would otherwise seek engagements as domestic servants. Such was the case in 1859, when Luton, Dunstable, and St. Alban's were very busy with the straw-plait trade. During that season, one single firm, Messrs. Vyse, purchased as much plait as 3000 persons could prepare, and made up 9000 straw hats and bonnets weekly. Men are engaged in cutting and sorting the straw, drying and brushing the plait, and stiffening and blocking the hats and bonnets when made; the other processes are undertaken by females. Taking all the branches, it was estimated in 1851 that 70,000 persons were thus employed in Great Britain, and that the yearly returns were 900,000*l.*; it is supposed that in 1859 these numbers were doubled. The manufacture of Brazilian grass hats is one of the peculiarities of the St. Alban's district. In the country places surrounding the three chief towns for the manufacture, straw-dealers buy straw from the farmers, sort and cut it, bleach it, and make it up into bundles. Weekly markets are held in the towns, at which the plaiters buy the straw. The women and girls make up the straw into plaits of various kinds and widths, which are either sold at once to itinerant dealers or middlemen, or are taken to market. The bundles of plait are bought by hat and bonnet makers, who either work at their own houses, or are employed in large establishments by the chief firms. These straw and straw-plait markets are held in the open streets of the three towns. No plaiters are employed by the manufacturers; the straw is bought already plaited, and ready to be made up into hats and bonnets. Much taste and skill are shown in the making of the better kinds of straw bonnets, and the weaver occasionally earns high pay. The manufacturers attend to all the fluctuations of fashion; and the workpeople have to adapt themselves to frequent changes in form, material, and manipulation.

A small import duty, formerly imposed on foreign straw-plait, was repealed in 1860.

STRAWBERRY. The botanical characters of the strawberry have been given in the NAT. HIST. DIV. Of the cultivated strawberry, the varieties are almost endless, and nearly every season something new is produced. In the Fruit Catalogue of the London Horticultural

Society, upwards of sixty varieties are named as worth cultivating, and there are as many, or perhaps more, which are reckoned worthless.

Strawberries may be propagated either by means of their suckers or runners, or by sowing seed. The young plants will generally bear the year after they have been planted or sown. In order to obtain the fruit in perfection, they should be planted where they have access to abundance of light and air. Plants grown from runners are best for new beds, and should be planted out in March, in beds with three or four rows, leaving an alley between each bed. The alleys should be wide, the beds kept clear from weeds, and the runners cut at least three times in the season. In the autumn the rows should be dug between, and in the spring some straw or dung should be laid between the rows. If the manure produces too luxuriant a growth of the plants, it should not be employed. The rows of the beds should be two feet apart, the plants eighteen inches asunder, and the alleys three feet wide between each bed. The duration of the plants is about three years. As they are diœcious, care should be taken that there are male plants in the bed in the proportion of about one to ten. The *wood-strawberry* is best produced from seed, which should be sown as soon as it is obtained from the fruit, and should be planted in beds in March, in the same way as the others. The *alpine strawberry* is best grown from seeds, which should not be sown till the spring, and may be planted in July or August, in rows at the back of hedges or walls, in a rich or moist soil. The duration of these and of the last seldom exceeds two years.

Strawberries, when ripe, may be eaten in almost any quantity without injury. They are frequently eaten mixed with sugar and cream, or wine. When ripe and well grown, they hardly require such additions; but when their sugar is deficient, this ingredient may be safely added; and the addition of wine under these circumstances should be preferred to cream, as the latter is very liable to disagree with disordered stomachs.

STRENGTH OF BEAMS, PILLARS, &c. [MATERIALS, STRENGTH OF.]

STRING-COURSE, a projecting *course* of masonry forming a *string* or horizontal line on the face of a wall, and consisting of a series of mouldings, as in Gothic, or of a flat surface (either plain or enriched), as in Italian architecture. In both styles, string-courses admit of great variety, and contribute very much to decoration, while they are in themselves essential members, inasmuch as they serve to define the internal division of the building, corresponding with the floors of the several stories; and by separating one tier of windows from another, to mark each as a distinct portion of the general composition, complete as regards itself, though secondary to the other. While they separate, they serve also to connect and combine the successive stages of a building; and to produce a due admixture of horizontal with perpendicular lines.

STRONTIA. [STRONTIUM.]

STRO'NTIUM (Sr). A peculiar metal found in combination with oxygen and carbonic or sulphuric acid, and forming the carbonate and sulphate of strontia. From the very considerable resemblance existing between baryta and strontia they were once supposed to be identical. Crawford and Sulze noticed a difference between them, and in the year 1792 Dr. Hope established sufficient differences to prove that they were completely distinct bodies, and the newly discovered body was named *Strontia* or *Strontites*, from Strontian in Scotland, the place in which it was discovered.

Strontium was procured from the carbonate of strontia by Davy in 1808; the method adopted is that which we have described for obtaining barium [BARIUM] from the carbonate of baryta. It is a malleable metal of a pale yellow colour, is heavier than sulphuric acid, fixed, difficultly fusible, and not volatile. When exposed to the air it attracts oxygen, and becomes converted into strontia; when thrown into water, it decomposes it with great violence, producing hydrogen gas, and forming with the water a solution of strontia.

Oxygen and Strontium, as just mentioned, readily unite, constituting the *protoxide, or strontia* (SrO), which in combination with acids exists largely in nature, and the *peroxide*, which is entirely an artificial product. The simplest mode of procuring the protoxide, or strontia, when required to be free from water, is to dissolve the native carbonate in nitric acid, and to decompose the crystallised nitrate obtained at a red heat; or the sulphate of strontia, which is a much more common substance, may be converted by the well known means first into sulphide and then into nitrate. The properties of strontia are, that it has a grayish-white colour; its specific gravity is between 3 and 4; it is very infusible, not volatile, has an acrid taste, and has an alkaline reaction on vegetable colours. On comparing these properties with those of baryta, it will be observed that there is considerable resemblance between them, but they differ in one remarkable respect, namely, that strontia, unlike baryta, is not poisonous. When exposed to the air it attracts carbonic acid, and is reconverted to the state of carbonate.

Strontia and Water combine to form at least two compounds: when a small quantity of water is poured upon strontia, it slakes, gives out heat, is rendered white, and becoming a hydrate, it is fusible at a white heat, but does not part with its water. Its formula is $SrOHO$.

According to Davy, strontia is soluble in about two hundred times its weight of water at common temperatures. The solution is called *Strontia Water*, and is occasionally employed as a chemical reagent; it acts energetically as an alkali on vegetable colours and in saturating acids. In boiling water strontia is much more soluble than in cold. As the solution cools, crystals, the primary form of which is a square prism, are deposited, and these appear to consist of $SrO, 9HO$.

Peroxide of Strontium (SrO_2) may probably be obtained, as the peroxide of barium is, by passing oxygen gas over strontia at a red heat, or by heating it with chlorate of potash.

Neither nitrogen nor hydrogen unites with strontium.

Chlorine and Strontium combine to form only one compound, consisting of ($SrCl$).

The best mode of procuring this salt is to dissolve carbonate of strontia in dilute hydrochloric acid, and to evaporate the solution to its crystallising point, the chloride containing water then separates in long slender crystals, which consist of one equivalent of chloride and one equivalent of water. When exposed to heat the water is expelled, and a solid white chloride remains. The crystals deliquesce in a moist atmosphere, are soluble in twice their weight of water at 60°, and still more so in boiling water; this salt is soluble also in alcohol, and the solution when burning exhibits the peculiar red flame characteristic of the compounds of this metal.

Chloride of strontium may be more directly, but less eligibly, prepared than in the mode now described, by passing chlorine gas over heated strontia; oxygen gas is expelled, and chloride of strontium remains.

Fluoride of Strontium (SrF) is an insoluble pulverulent compound.

Sulphide of Strontium (SrS) may be formed either by heating the native sulphate with charcoal, or by fusing strontia and sulphur in a green glass tube. It dissolves in hot water, and as the solution cools crystals of sulphide of strontium are formed. They appear to contain water.

This compound is used for the preparation of the salts of strontia, the sulphate being a much more common substance than the carbonate, which is preferable however when obtainable.

We shall now describe three oxisalts of strontia, two of which exist in nature, and the third is occasionally employed in chemical researches.

Carbonate of Strontia; Strontianite.—This was the first discovered compound of strontia; it occurs crystallised and massive. Primary form, a right rhombic prism. Cleavage, parallel to the lateral faces of the primary form. Fracture, uneven. Hardness, scratches carbonate of lime, but is scratched by fluor-spar. Colour, white, greenish, grayish, and brown. Streak, white. Lustre, vitreous. Transparent, translucent. Specific gravity 3·605.

Before the blow-pipe it fuses, and gives a purple light. It dissolves with effervescence in dilute nitric acid, and the solution is precipitated by sulphuric acid.

Massive Varieties.—Amorphous, globular. Structure fibrous, sometimes granular.

Found at Strontian in Scotland, Braunsdorf in Saxony, and in Peru.

Analysis by Klaproth :—

Carbonic acid	30·
Strontia	69·5
Water	0·5
	100·

Stromnite, or *Barystrontianite*, or *Barytiferous Carbonate of Strontia*, is a mineral found at Stromness in Orkney. It occurs massive. Structure fibrous. Hardness 3·5. Specific gravity 3·7. Lustre somewhat pearly. Translucent on the edges. Colour grayish and yellowish white. It is soft and brittle. Effervesces with acids, but does not melt before the blow-pipe.

According to Dr. Traill, who discovered this substance, it consists of—

Carbonate of strontia	68·6
Sulphate of baryta	27·5
Carbonate of lime	2·6
Oxide of iron	0·1
Loss	1·2
	100·

Carbonate of Strontia ($SrOCO_2$) may be artificially obtained by several processes; as by exposing strontia water to the air, or by adding an alkaline carbonate to it; or by decomposing any soluble salt of strontia, by means of an alkaline carbonate, &c. In whatever mode obtained, it is a colourless insipid powder, quite insoluble in water, decomposed by acids with effervescence, and by exposure to a high temperature. It is used for preparing the various salts of strontia.

Sulphate of Strontia; Celestin.—Exists largely in nature. It occurs crystallised and massive. Primary form a right rhombic prism. Cleavage easy, parallel to the base of the primary form, but less so in the direction of the lateral faces. Fracture conchoidal, uneven. Scratches carbonate of lime, but it is scratched by fluor-spar. It is brittle. Colour white, bluish, reddish-white. Transparent; translucent. Lustre vitreous. Specific gravity 3·858.

The *Massive Varieties* are nodular, tabular, and amorphous. Structure columnar, fibrous, granular.

It is not acted upon by acids. Before the blow-pipe it decrepitates and fuses into a white friable enamel. The powder becomes phosphorescent on a hot iron.

According to Klaproth it consists of—

Sulphuric acid	42
Strontia	58
	100

This substance occurs near Bristol, in Sicily, at Bex in Switzerland, &c.

Sulphate of Strontia and Baryta; Grunerite.—This mineral is found in Hanover. It occurs massive. Its structure is radiated. Hardness 3·0 to 3·5. Colour white, with sometimes a shade of blue. Translucent. Lustre vitreous. Specific gravity 3·76.

Sulphate of Strontia ($SrOSO_3$) may be obtained artificially, by adding sulphuric acid, or a sulphate, to any soluble salt of strontia. It is a colourless, insipid, heavy powder, insoluble in water, and dissolved only by strong sulphuric acid, from which it is precipitated by water.

Nitrate of Strontia ($SrONO_5$) is procured by dissolving the carbonate in dilute nitric acid, or by decomposing the sulphide of strontium with that acid. The solution is colourless, and by evaporation it crystallises in octohedrons, which are soluble in five parts of water at 60°, and in half a part at 212°. It is insoluble in alcohol, but when finely powdered and mixed with it, the alcohol burns with a beautiful red flame.

Under peculiar circumstances a hydrated nitrate of strontia is formed, containing four equivalents of water. The form of this is an oblique rhombic prism.

The salts of strontia are occasionally used in chemical investigations, and in giving a crimson flame to fire-works.

STROPHE (στροφή) is a set of verses composed according to a certain system of metres. The word is derived from στρέφω, "to turn," as in the lyric, especially the choral poetry of the Greeks, this part of a poem was sung during the movements and dances of the chorus. In modern times such a combination of verses, written either in the same or in different metres, is commonly designated by the Italian name stanza. The division of a poem into strophes was however applied by the ancients only to lyric poetry, and here one strophe seldom exceeded the number of four verses, with the exception of the dramatic and other choruses, in which a strophe sometimes contains a considerable number of verses. However different the metre of the several verses may be, there is always a unity of rhythm in them which characterises a strophe as an artistic whole. The various kinds of strophes were designated by the ancients by various names which either indicated the number of verses they contained, such as disticha, tristicha, tetrasticha, &c., or were derived from the name of their inventors, or from the characteristic metre in which they were composed, such as the Alcaic, Sapphic, Choriambic strophe, &c. Again, strophes in which all the verses are of the same metre are called monocola; and those consisting of verses of two, three, or four different metres, are called dicola, tricola, or tetracola. The choral poems of the Greeks generally consisted of three main parts, strophe, antistrophe, and epode. The antistrophe always corresponds in its metre with the strophe, and thus forms a second stanza, equal to the first; the epode differs from both, and forms the concluding stanza of a chorus. (G. Hermann, 'Elementa Doctr. Metr.')

STRO'PHULUS is an eruption of pimples upon the skin, which frequently occurs in infants whose health is disordered by the irritation of teething or any other cause. Dr. Willan describes the following forms of the disease:—

1. *S. intertinctus*, of which the vulgar name is Red-gum or Red-gown. The eruption in this form consists of vivid-red distinct papulæ, scattered in varying numbers over the cheeks, the arms, the backs of the hands, or, in some cases, the whole body. After an uncertain duration the papulæ disappear, the cuticle separating in scurf; but very frequently the fading of one eruption is rapidly followed by the appearance of another, which passes through similar stages, and generally spreads further over the skin. A few of the papulæ in each eruption sometimes assume the character of small pustules, a little fluid being formed in their apices: but this commonly disappears without bursting. The origin of the eruption may usually be traced to disorder of the digestive organs, by a gentle correction of which it may be cured. A sudden repulsion of it by exposure to the cold, or any injudicious remedies, may bring on diarrhœa, and even severe general illness. In itself it is a disease of no importance.

2. *S. albidus* differs from the preceding only in the colour of the papulæ, which consist of minute whitish specks, slightly elevated, and usually surrounded by a pale ring of red. They appear in the same situations as those of the first variety, are referrible to a similar origin, and require no other treatment.

3. *S. confertus* is often called the Tooth-rash, and the Rank Red-gum. It occurs only during the process of teething, and consists (in children of three or four months old) of small closely-set papulæ, less vivid but more permanent than those in *S. intertinctus*. Their usual seat is on the cheeks and sides of the nose; sometimes they extend to the forehead and the arms, and sometimes large papulæ appear upon the loins. If the eruption occurs when the infant is eight or nine months old, it generally assumes a severer form: one or two extensive patches appear on the arms, shoulder, or neck, the papulæ in each being hard, large, and set so closely, that the whole surface of the skin seems bright red. These usually continue for a fortnight, spreading slowly from one part to another, and then fade, leaving the part, after the exfoliation of the cuticle, rough and discoloured for a week or two longer. A similar, but more obstinate and painful form of eruption, sometimes appears on the lower extremities and the lower part of the trunk. It is never advisable however to adopt any active treatment for the remedy of this variety of the disease. It commonly continues during the whole of the early period of dentition; but it affords in some measure a safeguard against more serious disorders, and disappears soon after the first teeth have cut through the gums.

4. *S. volaticus* is characterised by small circular clusters of from six to twelve bright-red papulæ, which break out successively in many different parts of the body, remaining in each for about four days, and then becoming brown and disappearing with scurf. The complaint generally lasts three or four weeks, and passes in successive eruptions over a considerable part of the body. It is attended by slight fever and general disturbance of the system, and is most common in children of from three to six months old.

5. *S. candidus* is distinguished by the papulæ being larger than in any other variety. Their surfaces are smooth and shining, and, their bases not being inflamed, they seem paler than the adjoining skin: they usually last for about a week, and disappear in the same manner as those in the preceding forms. An eruption of this kind is most common in children a year old, who have shortly before its appearance suffered from some acute disease. It requires no active treatment: like all the other varieties of the disorder, it ceases with the irritation from which it has its origin.

STRUMA. [SCROFULA.]

STRYCHNIC ACID. [NUX VOMICA, ALKALOIDS OF.]

STRYCHNINE. [NUX VOMICA, ALKALOIDS OF.]

STRYCHNOS NUX-VO'MICA, *Medical Properties of.* The genus Strychnos, consisting of about twelve species, is remarkable for containing among these some which possess only mild or beneficent properties, while others are endowed with more potent and destructive powers than almost any other members of the vegetable kingdom. This extraordinary difference is presumed to be owing to certain species containing only an extractive, which is tonic and febrifuge, while others contain one, two, or three alkaloids, which are extremely poisonous. This is true as far as the *S. Nux-vomica*, *S. Ignatia*, *S. Colubrina*, and *S. Tieuté* are concerned, all of which contain either *Strychnia* or *Brucia*, and some both of these alkaloids; *S. Sancti Ignatii* contains an alkaloid called Igasurine [NUX-VOMICA, ALKALOIDS OF]; but it does not apply to the *S. toxifera* (Schomburgk), in which no alkaloid has been detected. It must be admitted, however, that the *S. toxifera*, though equally fatal with the others, produces death in a different way. Those possessed of an alkaloid destroy life by exciting tetanic spasms, while the *wourali*, or *worary*, or *urari* (prepared from the *S. toxifera*), produces diametrically opposite effects, as the muscles of voluntary motion are paralysed by it. The only species strictly officinal is the nux-vomica, poison-nut, or ratsbane, of which the seeds are employed, and to this our attention will be at present confined.

Strychnos Nux-vomica is a native of Coromandel, Malabar, Ceylon, and other parts of India, growing in sandy places, and attaining the size of a tree, but short, crooked, and sometimes twelve feet in circumference, flowering in the rainy season. The fruit is about the size of a St. Michael's orange, with a bitter astringent pulp, and containing from three to five seeds. The pulp may be eaten, but the seeds are poisonous and officinal; each seed is flattish or very slightly concave on the side of the umbilicus, convex on the other, thickened at the margin, peltate, about three lines in thickness, and clothed with dense grayish, silky, or velvety hairs, which towards the umbilicus are arranged in concentric circles. The testa or coat is thin, the nucleus white or grayish, hard, horny, or cartilaginous, bipartite or divided by a cavity in the centre; the embryo is near the margin of the seed, and its position is often indicated by a prominent point.

Owing to the hard cartilaginous nature of the seeds, they are extremely difficult to reduce to powder or to slice. Different expedients are adopted to accomplish this. The entire seed is devoid of odour, but the powder has a peculiar one, somewhat resembling liquorice; the taste is nauseously bitter. *Nux-vomica* should never be purchased in the state of powder, as it is frequently adulterated with common salt or even emery-powder.

An oil is expressed from the fresh seeds, which is used for burning.

Nux-vomica seems to exert a deleterious influence alike over vegetables and animals; there is, however, a difference of susceptibility to its action in different classes of animals, since a much larger quantity is necessary to destroy herbivorous than carnivorous animals.

The degree of effect varies with the quantity employed, but it seems to be the same in kind, being confined to the ganglionic system of nerves and the spinal cord, extending as high up as the *medulla oblongata*, and, according to Flourens, influencing even the *cerebellum*, but certainly not directly affecting the *cerebrum*. Hence in fatal cases the intellect is not disturbed till the extinction of life. The decapitation of animals does not hinder the characteristic action of *nux-vomica*, while, on the other hand, the removal of the spinal-marrow completely prevents its peculiar agency, even though artificial respiration be maintained. "From some experiments of Segalas, it appears also to exhaust the irritability of the heart; for in animals he found that organ could not be stimulated to contract after death, and life could not be prolonged by artificial breathing. *Nux-vomica* differs from all narcotic poisons, by not exhausting the sensibility. During the intervals of the fits the sensibility is on the contrary heightened, and the faculties acute." (Christison.)

Three distinct degrees of action may bè observed from the use of *nux-vomica*. In small doses the ganglionic system appears chiefly to be affected, and this so slightly, that any phenomena are observed only in cases of disease, particularly in hysterical and weak persons. The secretions are increased, both of the intestinal canal, the liver, the kidneys, and of the skin, accompanied with an increase of appetite and improved digestion. Hence, in small doses it is a useful adjunct to aperient and diuretic medicines.

It is in the second degree of action that the characteristic effects of *nux-vomica* begin to appear. The patient experiences a feeling of weight and weakness in the movements of the limbs, inducing him to remain at rest; while his mind is restless, sad, depressed, and anxious for solitude and darkness, as he is peculiarly sensitive to light, noise, or the movement of the surrounding objects. With an augmentation of the dose, these phenomena are increased, and the contact of any external body causes a feeling like an electric shock, the voluntary muscles are no longer under the control of the will, and the individual staggers on the least attempt at walking. At the beginning of these occurrences the pulse is hard and quickened; the gums, cheeks, and eyes reddened, and the respiration more frequent; but when the nervous system is more affected, the hardness of the pulse subsides, the countenance becomes of an ashy paleness, the eyes appear sunken, articulation is difficult and indistinct, breathing is laborious, and accompanied with violent spasms of the larynx, and the other muscles of respiration are irregular in their action. After these symptoms have lasted six or twelve hours, they subside, and a great increase of the secretions is observed to follow; itching of the skin, with much perspiration, even accompanied with an eruption of vesicles or large blebs; the secretions of the serous membranes, of the kidneys, and of the mucous membranes, are sensibly increased, those of the latter sometimes becoming bloody. During this period the patient complains of heat in the stomach and throat, of thirst, of foul taste, and rancid eructations, with nausea, and occasionally even vomiting. While the augmented secretions are taking place, the more prominent nervous symptoms disappear; and in a few days the sufferer recovers entirely from the debility and excessive sensibility.

The third degree of action manifests itself by tetanus and asphyxia, occurring in single paroxysms, alternating with paralytic torpor. The paroxysms become longer, and the remissions shorter, in which however, till death close the scene, the intellect remains unaffected. While the voluntary muscles are entirely withdrawn from the control of the will, the pulse sinks and becomes slower, the breathing more and more laborious ("the external muscles of the chest may be felt during the fits as hard almost as bone; and, according to an experiment of Wepfer, the diaphragm partakes of the spasm of the external muscles:" Christison). The belly swells and exhibits blue marks, the countenance is livid, and in a paroxysm of tetanic rigidity the breathing ceases, though the heart's action and the peristaltic motion of the intestines continue for some time; and, if an artery be opened, black carbonaceous blood issues. "Death, however, does not always take place by tetanus: in some cases the departure of the convulsions has been followed by a fatal state of general and indescribable exhaustion." (Christison.) Thus, after the spasms have lasted twelve, sixteen, or twenty-four hours, and completely disappeared, the individual has nevertheless died, after being apparently in a state of safety. This has been ascribed to the depressing effect on the heart's action, through the medium of the nervous system, of long-continued pain. Or the individual may suffer an attack, after the primary symptoms have subsided, of inflammation of the stomach and intestines, which may or may not prove fatal.

Vomiting does not always occur, though the name would seem to imply the frequency of this symptom.

Nux-vomica is important not only for its formidable properties, but for the illustrations it furnishes to certain physiological doctrines. Thus, when used in cases where a portion only of the body is paralysed, it excites convulsions in the paralysed part before any action be observed in the sound parts. "The paralysed parts are the seat of tetanic shocks, of a prickly sensation, and of a perspiration, which is not observed elsewhere. In hemiplegia the sound side of the body remains tranquil, while the affected one is the seat of extreme agitation; the tetanic attacks succeed each other rapidly, and an abundant exudation takes place. Even an anomalous eruption has been observed, while the healthy side has been perfectly free. One side of the tongue is sometimes sensible of a decidedly bitter taste, which is not perceptible on the other. If the dose be augmented, both sides become the seat of tetanic action, though not equally so." (Magendie.) It is also very remarkable that the contact of any external body with any part of the frame of an individual under the influence of *nux-vomica* which is supplied with nerves originating from the spinal cord, immediately excites convulsive actions. In persons poisoned by *nux-vomica*, whether the seeds or bark (false Angustura bark), the mere act of touching the skin to feel the pulse has excited again the convulsive motions. Of these two phenomena, namely, the action of strychnia on the paralysed limbs previous to causing any obvious effect on the sound organs, and of the contact of an extraneous body exciting the tetanic throes, the following explanation has been given by Mr. Grainger:—"Strychnia acts by preference on the paralytic limb or limbs, because the cerebral control is removed from the paralysed limb. If the cord be divided, the pure spinal power remaining, when the skin is touched the limb is retracted, and must be retracted, because the cerebral control is wanting. So when the spinal cord is stimulated by strychnia, it must act on the limb or limbs from which the cerebral power is withdrawn."

Nux-vomica acts most rapidly when introduced into a vein, and in other instances in the ratio of the absorbing power of the part; but it produces no effect when applied directly to a nerve or to the brain.

In fatal cases the morbid appearances vary according to the period at which death occurs. When death results from asphyxia, the brain is gorged with blood, and the texture softer than natural. When death takes place at a late period, sometimes appearances of inflammation are found in the stomach and intestines; but frequently these are absent. A tetanic stiffness remains in the corpse till decay commences: this state of rigidity, however, does not invariably occur.

The powerful properties of *nux-vomica*, and the rapidity of its action when administered in the state of a pure alkaloid, strychnia, or its salts, have deterred medical men from making so extensive a use of it as its therapeutic qualities entitle it to. The necessity for care in its administration is manifest from the facts, that death resulted in one instance merely from a woman grating cheese with a file which had been previously used to rasp seeds of *nux-vomica*; and in another instance death ensued from three grains of the alcoholic extract being taken at once. The consequence of a salutary dread of it being entertained has been that it is generally employed only as a last resource, instead of being used at an earlier period. It might, however, be beneficially used, with due caution and careful superintendence, in many cases of hysteria and hypochondriasis, dependent on irregular action of the nerves of the ganglionic system. In cases of hysterical paralysis, accompanied with greatly impaired sensibility, it would be more influential than any other agent in a disease at once tedious and distressing.

In paralysis it has been found more uniformly beneficial than most other remedies, though success has not always attended its employment. It is certainly better suited for some forms of paralysis than for others.

It is most serviceable in cases of paralysis of parts which derive their nerves from the ganglionic system or spinal cord. Hence it is more serviceable in *paraplegia* than in *hemiplegia*, in palsy of the bladder, of the rectum, and even in some cases of chronic diarrhœa dependent on atony of the intestines. It is more serviceable in the palsies which follow fevers, rheumatisms, repelled eruptions, habitual drunkenness, and exposure to noxious metals, such as lead or mercury, and merely depressed nervous power, than in those which result from effusion of blood. Its use is altogether improper immediately after an apoplectic seizure, and indeed whenever vascular fulness or organic disease of the brain is supposed to exist. Though less useful in affections of the nerves which arise from the brain, it has nevertheless proved beneficial in some cases of amaurosis, in which the endermic method of application has been employed, rather than the internal administration of it. Deafness has also been cured by it. When employed in paralysis of any of the limbs, an auspicious sign of its beneficial influence is a feeling of formication, and often of sweating, with or without an eruption, and spasmodic twitchings in the limb, while the rest of the body is unaffected.

It was conjectured by Batka, and it has since been proved by Dr. O'Shaughnessy, that the false Angustura bark [GALIPEA] was the bark of the *Strychnos nux-vomica*; so that in case of poisoning by that article, the same mode of treatment is to be pursued as in poisoning by nux-vomica or strychnia. "Nux-vomica bark (kuchila) is commonly sold in Calcutta for rohun, the harmless bark of *Soymida febrifuga*—a most dangerous substitution." (Pereira.)

Notwithstanding the "Act to regulate the Sale of Poisons" in this country, *nux-vomica*, compounded in various ways, is too freely sold, and used for nefarious purposes.

In cases of poisoning by *nux-vomica*, the most prompt treatment is necessary, and still more so if any of the soluble salts of strychnia have been taken. "Nux-vomica is occasionally made the instrument of voluntary death, although no poison causes such torture." (Christison.) The stomach-pump should instantly be had recourse to, when nux-vomica has been taken in powder; and as it adheres very obstinately to the coat of the stomach, it must be perseveringly used, with plenty of water. Emetics are too tedious in their action to be depended upon. M. Donné has recommended, when strychnia or any of its salts have been taken, to endeavour to form an insoluble salt; and for this purpose proposes chlorine, bromine, or iodine. The tincture of iodine may be procured promptly, but if ten minutes elapse before it be administered, it is unavailing. When the quantity of strychnia taken is not large, nor the symptoms very urgent, vital stimulants or sedatives are often sufficient; and for this purpose, wine, brandy, or a mixture of acetous ether and laudanum, or laudanum alone, will remove the present danger. Chloroform is sometimes successful, as is also ice applied along the spine. Conium or its tincture offers probable means of antagonising the action of strychnia, as suggested by Dr. Pereira. It is said that the leaves of the *Feuillea cordifolia* furnish an antidote to nux-vomica and several other vegetable poisons. It must ever be remembered that the danger is not entirely removed, though the spasms may have subsided, and the respiration become easy. Inflammation of the stomach may supervene, which will require the usual treatment, or secondary asphyxia may steal on, and destroy the patient. To prevent this last occurrence, great watchfulness is necessary, especially during the night, and the patient should be frequently awakened, and made to drink freely of green tea. But perhaps the most potent and efficient antidote to the other poisonous strychnias would be the urari poison of South America, as suggested by Mr. Morgan. (See Morgan's 'Lecture on Tetanus,' p. 31.) The preparation of this substance, which has been an object of curiosity and interest since the time of Sir Walter Raleigh, has been fully detailed by Sir Robert Schomburgk. ('Annals of Natural History,' vol. vii.) It is an article of much importance to the natives of Guiana, as much of their means of subsistence depends upon their possessing this poison, in which to dip their arrows for the chase. The chief, if not the only, active ingredient is the *Strychnos toxifera* (Schom.), and perhaps, in some places, *Strychnos cogens* (Bentham), the other ingredients (most of which are obtained from climbing plants, lianos, or "nebbees," except one bulbous plant, a cissus, and another supposed to belong to the *Xanthoxyleæ*) are used only to bring the juice to a proper degree of consistency and adhesiveness. Arrows dipped in it have been known to retain their poisonous properties for twenty-seven years. (Iliff, in 'Medical Gazette,' vol. xx., p. 261.) The poison when inspissated may be rendered liquid by heat, and is soluble in water, in alcohol, in hydrochloric acid, and in volatile alkaline spirit. It unites with acids without commotion or change of colour. If it be united with alkalies, no ebullition is observable, but it changes its colour from a dark brown to a yellowish-brown. It possesses a remarkable influence over the blood after it is taken from a vein. "A few grains, mixed with as many ounces of human blood warm from the veins, entirely prevents a separation of serum and crassamentum, and the whole mass continues in a state of fluidity similar to that in which it was drawn, until, after some days, it putrifies." (Bancroft.) This property seems to point out the propriety of employing it in cholera, in which the separation of the serum from the crassamentum, while the blood is yet in the body, is one of the most remarkable symptoms of that disease. Dr. Hancock is of opinion that it is one of the most potent sedatives in nature, and, could it be safely managed, he had no doubt it might become a valuable remedial agent in the treatment of spasmodic or convulsive disorders. Its taste is an agreeable bitter, and it has a tonic and febrifuge effect, frequently proving a valuable cure in intermittents. It, as well as the venom of the viper, seems to be disarmed of its virulence by undergoing the process of digestion.

On account of the difficulty of preparing the alcoholic extract of *nux-vomica* of uniform strength, strychnia, or some of its soluble salts, is now generally substituted for it, as these admit of easy subdivision of the dose. Sulphate of strychnia has been used in some cases with great advantage (See Gaskoin, in 'Med. Gaz.,' vol. x., p. 316); so also the acetate; but a form of preparation which has proved of service in some long-standing and almost hopeless cases of paralysis, is the hydriodate of strychnia. (See Magendie, 'Formulaire.') Phosphate is also used; and in Germany nitrate is much used.

Care must be taken that the strychnia be pure, as a spurious article is vended in France, which contains no trace of strychnia. Bichloride of mercury is a good test for strychnia, but it causes no precipitate from the solution of the acetate of strychnia; but the addition of hydrochloric acid causes a white crystalline precipitate. Sulphocyanodide of potassium appears to be the best test for strychnia. (See 'British Annals of Medicine,' vol. i., p. 190.)

Strychnia is prepared either from the *nux-vomica* seeds, in which case it is difficult and expensive to separate it from the brucia, or it is obtained from the St. Ignatius bean, in which it exists in about three times larger quantity than in *nux-vomica*. It is also, but rarely, procured from the *Strychnos Colubrina*. The purest and most easily obtained is furnished by the *Strychnos Tieuté*, but the rarity of this substance is a practical obstacle to its employment. Igasurina will probably be found to act like the others, but more mildly.

Snake-wood.—Many substances, in countries infested with serpents, are reputed to be efficacious in counteracting the poisonous bites of these reptiles: one of the most celebrated of these is the root of the *Strychnos Colubrina*. The strychnia probably acts as an antagonist to the stupifying effects of the poison of the snake, just as arsenic does to the poison of the *Coluber carinatus* of the West Indies. [ARSENIC.]

Strychnos potatorum, called also *S. Tettan Cottay*, or Clearing-nut, is a native of India, and is a larger tree than any other species. It is devoid of noxious properties. The fruit, though when very young it is made into a preserve, and eaten, is reckoned emetic by the native doctors. The chief use made of it is to rub the seeds hard round the inside of an earthen pot, into which water is poured, and in a short time it becomes clear, tasteless, and wholesome, however muddy, brackish, or putrid it may have been: hence its name of clearing-nut. Officers and soldiers, before setting off on a march, provide themselves with a store of these, as water purified by such means is deemed more wholesome than that clarified by alum.

Strychnos pseudo-china, Quina do Campo, or Field China, is a native of Brazil (St. Hilaire, 'Plantes Usuelles de Brésil,' t. 1), and is devoid of strychnia or brucia. It is a remedy of the Sertaneias, being peculiarly fitted for those cases to which the true cinchonas are unsuitable. The taste is at first faintly aromatic, then astringent, and at last slightly bitter. It has no odour. In its properties it resembles quassia, menyanthes, or gentian more than the true cinchonas, with none of which, except the humalia bark, could it readily be confounded in its physical characters. Mr. Burchell says, however, that even in the proper localities of the cinchonas many strychni are collected. [CINCHONA, in NAT. HIST. DIV., col. 1081.]

STUCCO. A name sometimes, though incorrectly, applied to all descriptions of lime or cement renderings on masonry, whether external or internal, but which is really given by builders to a species of plastering, in ordinary cases worked up by hand to a fine face adapted to receive paint; or in superior buildings made by the addition of other materials than the lime, or plaster, usually employed, in order to resemble marble. Common stucco, in fact, is nothing more than plastering which has received an additional amount of manipulation; marble stucco is made with fine lime (composed of the pure hydrate of that base) mixed with calcareous powder, chalk, or other analogous substances in such proportions and worked in such manner as to produce a hard, uniform surface, which admits of being coloured, painted, and polished so as to represent valuable marbles. It is employed in decorative architecture to cover columns, pilasters, walls, cornices, plinths, &c., in sheltered or covered positions: in external works, the natural or the artificial calcareous cements, or the oleaginous cements, are employed for this purpose—a distinction unknown by the Italians who first used the "stucca tura," from whence we have derived the art, and the name, of the fine plastering used by us exclusively for decorative and internal works.

Uniform marble stucco is prepared by mixing pounded white Carrara marble, or gypsum in the form of the white alabaster, with rich lime carefully slaked and run through a sieve, and the mixture is trowelled on to a rough rendering coat until the surface is perfectly even and homogeneous. Different colours are communicated by the addition of the metallic oxides, and when very delicate tints are required plaster mixed or gauged with water containing size, fish-glue, or gum arabic, is substituted for the hydrate of lime. The polishing is only commenced when the surface is perfectly dry, and it is effected by the use of fine grits, tripoli powder, chalk, and oil; very much in the same manner that marble is polished. Scagliola is executed with the same class of materials as the marble stuccos; but small splinters (or *scagliole*) of the marble desired to be imitated, should the latter present much variety of effect, are introduced in the finishing coats. Of late years the Keene's and the Parian cements have been exclusively used in London, instead of the ancient marble stuccos.

STURM'S THEOREM. There is a branch of the theory of equations, containing the celebrated theorems of Descartes, Fourier, and Sturm, which it is advisable to place in an article by itself, and the present heading has been chosen because Sturm's theorem is at once the most conclusive and the latest of the three. It has long been a problem of much interest and notoriety to find, in a given equation, how many roots, if any, are contained between two given limits; how many roots are positive, how many negative, how many imaginary.

The first step towards the solution of the preceding problem was made by Descartes, though it is asserted by Cossali and Libri, that Cardan came very near to the same step. Cossali, after collecting a table of Cardan's cases, and putting them in a form which Cardan did not use (an equation with 0 on the second side), then says that an analyst who should look at this table would be able to rise to Descartes's theorem. This is true enough, but it does not prove that Cardan either could or did make the invention, but the contrary. All the world knows that mathematical discoveries are recognised often enough by analysts of a later day, in rudiments from which the fabricators of them could evolve nothing.

The theorem of Descartes, expressed in his own words, is as follows ('Geometria,' lib. iii.): "Ex quibus etiam cognoscitur, quot veræ et quot falsæ radices in unaquaque Æquatione haberi possint. Nimirum, tot in ea veras haberi posse, quot variationes reperiuntur signorum + et −; et tot falsas quot vicibus ibidem deprehenduntur duo signa +, vel duo signa −, quæ se invicem sequuntur." That is, that an equation may have as many positive roots as there are changes of sign in passing from term to term, and as many negative roots as there are continuations of sign; but not more of either kind. It has been doubted whether Descartes knew the true meaning of his own theorem as to the case of imaginary roots; this doubt is as early as the time of Descartes himself, who replies in a letter which we cannot find by means of Rabuel's reference to it. This is however of little consequence, as the following sentence (also from the Geometry) shows in what manner Descartes understood his own words: "Cæterum radices tam veræ quam falsæ non semper sunt reales, sed aliquando tantum imaginariæ; hoc est, semper quidem in qualibet Æquatione tot radices quot dixi, imaginari licet; verum nulla interdum est quantitas quæ illis, quas imaginamur, respondet." It would seem then that Descartes not only remembered the limitation of the theorem arising from the possible existence of imaginary roots, but proposed to divide those last roots themselves into two classes corresponding to the true and false (or positive and negative) of the real roots. The next step was made by De Gua (1741), who showed that the roots of an algebraical equation $\phi\,x=0$ are never all real, unless the roots of the derived equations $\phi'\,x=0$, $\phi''\,x=0$, &c. be also all real; $\phi'\,x$, $\phi''\,x$, &c. being the derived functions, or differential coefficients, of $\phi\,x$. He also showed how to determine the conditions of the reality of all the roots. (Lagrange, 'Res. des Equ. Numer.', note viiii.; Peacock, 'Report,' &c., p. 327.)

Descartes's theorem would be perfect if the roots of equations were always real. For example, take $x^2-13x+40=0$. If the roots be real, they are both positive; write $x+6$ for x [INVOLUTION AND EVOLUTION], and we have $x^2-x-2=0$, of which the roots are less by 6 than those of the former equation. But in the second equation, one root is negative and one positive; consequently the roots of the first equation are one greater and one less than 6. In the same manner a more complicated case might be treated.

The theorem of Descartes, and the notion derived from it, that the order of signs of coefficients regulates the signs of the roots; with the step made by De Gua, and the notion derived from it, namely, that the derived functions must be consulted upon the question whether the roots of an equation be real or not; and the common theory of equal roots, namely, that when $\phi\,x=0$ has m equal roots, $m-1$ of its derived functions (neither more nor fewer) vanish at the same time, or with the same root,—were the hints on which FOURIER [BIOG. DIV.] was able to make an advance upon his predecessors. The coefficients of the equation are themselves nothing but the *divided* derived functions on the supposition that $x=0$. Thus, if $\phi x = 3x^3 - 7x^2 + 11x + 4$, we have

$$\phi 0=4,\quad \frac{\phi'0}{1}=11,\quad \frac{\phi''0}{1.2}=-7,\quad \frac{\phi'''0}{1.2.3}=3.$$

Let ϕx, $\phi_1 x$, $\phi_2 x$, &c. be the function in question, and its divided derived functions. If we make x great enough and negative (say infinite and negative), the signs of these functions are all alternate, that is, the series yields nothing but changes of sign in passing from term to term. But if we make x great enough and positive (say infinite and positive), the series yields nothing but permanences of sign. Thus, in the preceding expression we have

	$x=-\infty$	$x=0$	$x=+\infty$
ϕx	−	+	+
$\phi_1 x$	+	+	+
$\phi_2 x$	−	−	+
$\phi_3 x$	+	+	+
	nothing but changes.	two changes.	no changes.

$\phi x=3x^3-7x^2+11x+4$, $\phi_1 x=9x^2-14x+11$, $\phi_2 x=9x-7$, $\phi_3 x=3$.

Now Descartes's theorem tells us that there *may* be *one* negative and *two* positive roots, and we see that in passing from $x=-\infty$ to $x=0$, or through the whole range of negative quantity, there is *one* change of signs lost; while in passing from $x=0$ to $x=+\infty$, or through the whole range of positive quantity, *two* changes of sign are lost. Fourier's theorem would suggest itself as highly probable to any one who put Descartes's theorem in the preceding form: it is as follows:—When $x=a$, let the signs of ϕa, $\phi_1 a$, $\phi_2 a$, &c. be ascertained, and let this be called the criterion series, or simply the criterion. Then in passing from $x=a$, the less, to $x=b$, the greater (greater and less being understood in the algebraical sense), the criterion never acquires changes of sign, though it may lose them. When m changes of sign are lost to the criterion in passing from $x=a$, the less, to $x=b$, the greater, it follows that there are either m real roots of the equation lying between a and b, or some number, p, of pairs of imaginary roots, and $m-2p$ real roots lying between a and b. If m be odd, there must be at least one real root lying between a and b. And if no changes of sign be lost in passing from a to b, there is certainly no root lying between a and b. For example, examine the preceding function and its derivatives when $x=-1$ and $x=+1$. In the former case the criterion is − + − + (three changes), and in the latter + + + + (no changes). Three changes then are lost to the criterion in passing from −1 to +1: so that there are either three real roots, all lying between −1 and +1; or one such real root and two imaginary roots. Again, in passing from −1 to 0, one change is lost: there is certainly then one negative root between −1 and 0. The remaining roots are then either both imaginary, or positive and lying between 0 and 1: the least consideration of the equation will show that the former is the case.

Fourier's theorem is proved as follows:—changes of sign take place only when quantities become nothing or infinite; those before us cannot become infinite, and therefore the criterion can never be disturbed except when one or more of the set ϕx, $\phi_1 x$, &c. vanish. Now when any function ψx, vanishes, say at $x=a$, its previous sign must have been the contrary of that of its derived function, and its subsequent sign the same; that is, in passing from $a-h$ to $a+h$, h being very small, $\psi' x\times\psi x$ must pass from negative to positive. An algebraical proof may be given of this, but none which in brevity comes near to the following. The function $\psi' x\times\psi x$ is the derived function or differential coefficient of $\frac{1}{2}(\psi x)^2$, a positive quantity. Now if $\psi a=0$, $\frac{1}{2}(\psi x)^2$ must diminish (being positive) from $x=a-h$ to $x=a$, and increase from $x=a$ to $x=a+h$. But a differential coefficient is negative when its function diminishes with an increase of the variable, and positive when its function increases with an increase of the variable. Consequently $\psi' x\times\psi x$ is negative from $x=a-h$ to $x=a$, and positive from $x=a$ to $x=a+h$; as asserted. We now proceed to the proof of the theorem.

1. When $x=-\infty$, the criterion is + − + − &c. or − + − + &c.; and when $x=+\infty$, it is + + + &c. or − − − &c. This follows immediately from the nature of the functions ϕx, $\phi_1 x$, &c., in which, when x is numerically great enough, the sign is always governed by that of its highest term. Thus, in some place or places, so many changes are certainly lost as there are units in the dimension of ϕx, *neither more nor fewer*, unless changes be gained and afterwards lost.

2. When x passes through a root of ϕx, as many changes are lost as there are roots of ϕx equal to that root. Let there be only one root equal to a, so that $\phi_1 a$ does not vanish. We have then one or other of the following:—

	$x=a-h$	$x=a$	$x=a+h$		$x=a-h$	$x=a$	$x=a+h$
ϕx	(+)	0	(−)	ϕx	(−)	0	(+)
$\phi_1 x$	−	−	−	$\phi_1 x$	+	+	+
	One change lost.				One change lost.		

The signs in parentheses are those which follow from the theorem above proved. $\phi_1 x$ cannot change its sign in the process, for by hypothesis it does not vanish when $x=a$, and we take h so small that there shall be no root of $\phi_1 x$ between $a-h$ and $a+h$. At $x=a-h$, we must have $\phi_1 x\times\phi x$ negative, and at $x=a+h$ we must have it positive, by the theorem; which gives the signs in parentheses as marked.

Now let there be, say five roots equal to a, or let ϕa, $\phi_1 a$, $\phi_2 a$, $\phi_3 a$, $\phi_4 a$ all vanish, $\phi_5 a$ not vanishing. We must have then one or other of the following:—

	$x=a-h$	$x=a$	$x=a+h$		$x=a-h$	$x=a$	$x=a+h$
ϕx	+	0	−	ϕx	−	0	+
$\phi_1 x$	−	0	−	$\phi_1 x$	+	0	+
$\phi_2 x$	+	0	−	$\phi_2 x$	−	0	+
$\phi_3 x$	−	0	−	$\phi_3 x$	+	0	+
$\phi_4 x$	+	0	−	$\phi_4 x$	−	0	+
$\phi_5 x$	−	−	−	$\phi_5 x$	+	+	+
	Five changes lost.				Five changes lost.		

All the signs except those in the lowest line are dictated by the preliminary theorem. Thus $\phi_5 x$, in the first case, is negative by hypothesis; now $\phi_5 x$ is $\phi'_4 x\div 5$, so that $\phi_5 x\times\phi_4 x$ must be negative before $\phi_4 x$ vanishes, and positive afterwards. Hence $\phi_5 x$ continuing negative, $\phi_4 x$ must change from positive to negative. Again, $\phi_4 x\times\phi_3 x$ makes a similar change. The least consideration will show that, the signs in the lowest line being given, those in all the upper ones must be as written.

3. When intermediate functions vanish, changes of sign are never gained, but only lost; and are never lost but in even numbers. Suppose, for instance, that $\phi_1 a$ vanishes, but not ϕa nor $\phi_2 a$. We have then one of the four following:—

	$x=a-h$	$x=a$	$x=a+h$		$x=a-h$	$x=a$	$x=a+h$
ϕx	+	+	+	ϕx	−	−	−
$\phi_1 x$	+	0	−	$\phi_1 x$	+	0	−
$\phi_2 x$	−	−	−	$\phi_2 x$	−	−	−
	No change lost.*				*Two* changes lost.		
ϕx	−	−	−	ϕx	+	+	+
$\phi_1 x$	−	0	+	$\phi_1 x$	−	0	+
$\phi_2 x$	+	+	+	$\phi_2 x$	+	+	+
	No change lost*				*Two* changes lost.		

The signs in the middle lines are dictated by the preliminary theorem. Next let $\phi_4 a$, $\phi_5 a$, $\phi_6 a$, $\phi_7 a$ vanish, but not $\phi_3 a$ nor $\phi_8 a$. We have then, by the preliminary theorem, one or other of the four following:—

	$x=a-h$	$x=a$	$x=a+h$		$x=a-h$	$x=a$	$x=a+h$
$\phi_3 x$	+	+	+	$\phi_3 x$	−	−	−
$\phi_4 x$	−	0	−	$\phi_4 x$	−	0	−
$\phi_5 x$	+	0	−	$\phi_5 x$	+	0	−
$\phi_6 x$	−	0	−	$\phi_6 x$	−	0	−
$\phi_7 x$	+	0	−	$\phi_7 x$	+	0	−
$\phi_8 x$	−	−	−	$\phi_8 x$	−	−	−
	Four changes lost.				Four changes lost.		
$\phi_3 x$	−	−	−	$\phi_3 x$	+	+	+
$\phi_4 x$	+	0	+	$\phi_4 x$	+	0	+
$\phi_5 x$	−	0	+	$\phi_5 x$	−	0	+
$\phi_6 x$	+	0	+	$\phi_6 x$	+	0	+
$\phi_7 x$	−	0	+	$\phi_7 x$	−	0	+
$\phi_8 x$	+	+	+	$\phi_8 x$	+	+	+
	Four changes lost.				Four changes lost.		

* Observe that in these cases a change is removed to a higher place in the series, nearer to the head of the criterion.

The same conclusions will be found from other cases, and we have now examined every way in which the criterion can undergo an alteration in the order of the signs of which it is composed. And since, the function being of n dimensions, there are altogether n changes, and n only, to lose, it follows that every pair of signs lost by the vanishing of any of the derived functions, in any internal part of the criterion, shows that there must be two imaginary roots: for there must be n roots only, every real root must be accompanied by a change lost at the head of the criterion, and every loss of changes which takes place anywhere else diminishes the number which can take place at the head. Again, since losses other than at the head of the criterion must take place in even numbers, it follows that of any odd number of losses, one must have been effected at the head, or must have risen from a real root; or if not one, some other odd number.

The manner in which the changes of sign take place is as follows:— When $x=-\infty$, or even when it is numerically greater than any negative root, the criterion presents nothing but changes. Alterations of the criterion consist in: 1, Loss of one or more changes at the head of the criterion (showing real roots); 2, loss of changes in even numbers in the middle of the criterion (showing imaginary roots); 3, elevation of changes, or alteration of their place in a direction towards the head of the criterion. This last takes place only when an *odd* number of derived functions vanishes, the including functions (preceding and following) having different signs. So soon as a root has been passed, there is a permanency + + or − − at the head of the criterion; before another root is arrived at, this permanence must have become a change, since a change there must then be at the head to be lost in passing through the root. Hence it follows that between two roots of $\phi x=0$, there must lie a root of $\phi' x=0$; and this root is either single, triple, quintuple, &c., but not double, quadruple, &c.

For example, let $\phi x=x^4-7x^3+15x^2-10x+2$,

$\phi_1 x=4x^3-21x^2+30x-10$, $\phi_2 x=6x^2-21x+15$,

$\phi_3 x=4x-7$, $\phi_4 x=1$.

There are no negative roots, as is obvious from their being nothing but changes among the co-efficients; if we construct the criteria for $x=0, 1, 2, 3$, and 4, we find the following results:—

	0	1	2	3	4
ϕx	+	+	+	−	+
$\phi_1 x$	−	+	−	−	+
$\phi_2 x$	+	0	−	+	+
$\phi_3 x$	−	−	+	+	+
$\phi_4 x$	+	+	+	+	+

When $x=0$, the criterion shows four changes; at $x=1$, it is indefinite, owing to $\phi_2 1=0$. But immediately before $x=1$, $\phi_2 x$ must, by the preliminary theorem, have the sign contrary to that of $\phi_3 x$, or the sign +; consequently, for $x=1-h$, however small h may be, the criterion must be + + + − +. Two changes of sign are therefore lost in passing from $x=0$ to $x=1$, and there are either two real roots between 0 and 1, or two imaginary roots. To try this further, let $x=\frac{1}{2}$, the criterion of which is − + + − +; so that there is one root between 0 and $\frac{1}{2}$, and another between $\frac{1}{2}$ and 1. When $x=1+h$, the criterion is + + − − +, so that there is no root between 1 and 2. Lastly, there is one root between 2 and 3, and one between 3 and 4.

The theorem of Fourier, though very convenient in practice, is defective in theory, as requiring an indefinite number of trials. If two roots were very nearly equal, it would require very minute subdivision of the interval in which they are first found to lie, to distinguish them from a pair of imaginary roots. This theorem was not published till 1831, in Fourier's posthumous work, but its author had made his methods known, and among others to the late M. Sturm, a young Genevese, employed in the bureau of M. de Férussac, editor of the bulletin which bore his name, afterwards a member of the Institute, who died a few years ago. Sturm applied himself to the detection of functions which should stand in the place of ϕx, $\phi_1 x$, $\phi_2 x$, &c., in such manner that the criterion formed from them, in the same way as in Fourier's theorem, should never lose a change of signs except in passing through a real root. In this he signally succeeded; and thus, though his theorem presents great practical prolixity of detail, he furnished a complete solution of the difficulty which had occupied analysts since the time of Descartes. This theorem may be proved as follows:—

Let there be any number of functions $V, V_1, V_2, \ldots V_r$, the last of which is a constant independent of x, and all but the last are functions of x. Let them be connected together by the equations—

$$\begin{aligned} V &= P_1 V_1 - V_2, \\ V_1 &= P_2 V_2 - V_3, \\ V_2 &= P_3 V_3 - V_4, \\ &\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot \\ &\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot \\ V_{r-2} &= P_{r-1} V_{r-1} - V_r. \end{aligned}$$

$P_1 P_2$, &c., being any functions of x, which do not become infinite when $V_1 V_2$, &c., vanish. From this it follows, first, that no two consecutive functions of the set V, V_1, &c., can vanish together; for if V_2 and V_3, for instance, vanished together, the third equation shows that V_4 would also vanish, the fourth that V_5 would vanish, and so on; consequently V_r, a given constant, also vanishes, which is absurd. Secondly, when any one after V vanishes, the preceding and following must have different signs; for $V_1=0$ gives $V=-V_2$, $V_2=0$ gives $V_1=-V_3$, &c. Now call the signs of V, V_1, &c., the criterion, and let $V=0$ when $x=a$, there being only one root of that value, so that V changes sign in passing from $x=a-h$ to $x=a+h$. Since V_1 does not vanish with V, we have one of the four cases following:—

	$x=a-h$	$x=a$	$x=a+h$	$x=a-h$	$x=a$	$x=a+h$
V	−	0	+	+	0	−
V_1	−	−	−	−	−	−
V	−	0	+	+	0	−
V_1	+	+	+	+	+	+

If V_1 be the derived function of V, only the second or third cases can happen, by the theorem so often used in the preceding part of this article; so that a change of sign will be lost at the head of the criterion for every single root of $V=0$. Nor will any change of sign ever be gained or lost in any other manner; for suppose $x=a$ gives $V_4=0$ for instance, then V_3 and V_5 have different signs, and in passing from $x=a-h$ to $x=a+h$, if each be so small that no root of V_3 or V_5 lies between $a+h$ and $a-h$, we must have one of the following cases:—

	$x=a-h$	$x=a$	$x=a+h$	$x=a-h$	$x=a$	$x=a+h$
V_3	−	−	−	+	+	+
V_4	±	0	±	±	0	±
V_5	+	+	+	−	−	−

In no one of these is any change of sign lost, or anything except a change and a permanence when $x=a-h$, and a change and a permanence, in a different order perhaps, when $x=a+h$. Consequently, if in passing from $x=a$, the less, to $x=b$, the greater, it appear that no changes of sign are lost, it is certain that there must have been no real roots of $V=0$ between $x=a$ and $x=b$.

Now, V_1 being the derived function of V, it remains to find V_2, V_3, &c. Divide V by V_1, which is of one dimension lower, and we have a quotient, say P_1, and a remainder R_1. Then $V=P_1\ V+R$ or $V_2=-R$. Again, divide V_1 by V_2, giving a quotient P_2, and a remainder R_2: we have then $V_1=P_2\ V_2+R_2$ or $V_3=-R_2$; and so on. It appears, then, that V_r, being the derived function of V, we must proceed as in finding the greatest common measure of V and V_1, only changing the sign of every remainder as fast as it is obtained. In order that the last, V_r, may be a finite constant, it is requisite that there should be no equal roots. We must then suppose the equal roots to be separated beforehand, as in the usual method. In fact, this very process of finding the greatest common measure, with or without change of sign in the remainders, will first detect the equal roots, if any. It is important to remark, that at any step multiplication by any positive quantity is allowable, the signs (the only things we have to do with) not being in any case altered by such multiplication.

In INVOLUTION AND EVOLUTION a method of performing the operations required in Sturm's theorem was proposed, which avoids useless writing. Mr. Young ('Math. Dissertations,' p. 143) proposed another, of much the same degree of abbreviation. Sturm's theorem however requires so much operation, that there can be little doubt of that of Fourier being a more easy mode of working any particular case. It is not however as a key to the mere numerical solution of equations that either of these theorems must be viewed: the insight which they give into the nature of equations, and still more that which they are likely hereafter to give (for neither is more than a germ), will render them both important steps in the progress of algebra.

Since it is sufficient to the theorem that the last function V_r should retain one sign, and not vanish, we may stop in the process when we arrive at any function of which all the roots are known, or can be discovered, to be impossible. And it is easily shown, as was done by Sturm himself, that even when there are equal roots, so that the last, V_r, is neither constant nor always of the same sign, the theorem still remains true, so far as to give the number of *different* roots which lie between any two given limits, without any information as to the number of times which each root should be repeated.

For instance, in the article cited we find

$$\begin{aligned} V &= x^4-3x^3-2x^2+x-3 \\ V_1 &= 4x^3-9x^2-4x+1 \\ V_2 &= 43x^2+45 \end{aligned}$$

We need not go further, for V_2 has none but imaginary roots. Now when $x=-\infty$, the criterion is + − +; when $x=0$, it is − + +; and when $x=+\infty$, + + +. Consequently there is one negative root, one positive root, and a pair of imaginary roots.

The following example is from Mr. Young (p. 191): it is an instance given by Fourier in illustration of his own method, and Sturm's is applied to it by Mr. Young, to show the superior certainty of the latter. Of that certainty no one can doubt, but the process exhibited in the page cited is such as will never come into general use unless the work can be made more easy:—

$$\begin{aligned}
\mathrm{v} &= x^7-2x^5-3x^3+4x^2-5x+6\\
\mathrm{v}_1 &= 7x^6-10x^4-9x^2+8x-5\\
\mathrm{v}_2 &= 2x^5+6x^3-10x^2+15x-21\\
\mathrm{v}_3 &= 62x^4-70x^3+123x^2-163x+10\\
\mathrm{v}_4 &= -4403x^3+8862x^2-19810x+20531\\
\mathrm{v}_5 &= 200865x^2+489790x-1169472\\
\mathrm{v}_6 &= 187355x-270632\\
\mathrm{v}_7 &= \text{a positive constant.}
\end{aligned}$$

Here the criteria for $x=-\infty$, $x=0$, $x=+\infty$ are

$$\begin{array}{lll}
x=-\infty & -+-+++-+ & \text{five changes}\\
x=0 & +--++--+ & \text{four changes}\\
x=+\infty & ++++-+++ & \text{two changes.}
\end{array}$$

There are then one negative root and two positive roots, and therefore four imaginary ones. The reader will easily find that the positive roots lie between 1 and 2, and the negative root between -1 and -2. The exhibition of the process, leaving out the actual performance of multiplications, has 400 figures in Mr. Young's work. Fourier has merely written down the derived functions, which is done at sight, and formed the criteria for $x=-10$, $x=-1$, $x=-h$, $x=0$, $x=+h$, $x=1$, $x=10$, which may all be done at sight also. From this he finds that there must be one negative root between -1 and -10, that there may be two roots between 0 and 1, and two more between 1 and 10. All this might be done before v_4 could be found and written down as above. It is to be hoped either that Fourier's theorem will be completed by the addition of a test for imaginary roots, or that Sturm's functions will be exchanged for others of less complicated operation. But in the meanwhile it must be remembered that Fourier, Sturm, and Horner have completely changed the aspect of the solution of numerical equations: at the beginning of the period mentioned, it would have been thought too good to expect that any certain method of predicting, or easy one of calculating, the roots of such equations, should be found, after the failure of all analysts from Descartes and Newton down to Euler and Lagrange, the best heads of France and England, Germany and Italy. It is a lesson against despairing of the attainment of any result, however illustrious the investigators who have not succeeded, and also against imagining that the hints of preceding ages are exhausted. All the contents of the present article arise out of a new mode of looking at the theorem which Descartes gave more than two hundred years ago.

STYLE, used for manner of writing, from the Latin *stylus*, the same word with the Greek *στύλος*, a "pillar," or "column." The Romans gave that name to an iron bodkin having a sharp point, with which they were accustomed to write by exaration, or scratching, on their wax-covered tablets or note-books; and from the instrument of writing, the term was transferred to the writing itself, and that too considered in reference not to the form of the characters (which would have been the more immediate transition), but to the mode of expression. Among the Romans, however, the term, in this figurative application of it, retained always considerably more of its antecedent meaning than it does with us. We say not only style of writing and style of speaking, but style of painting, style of architecture, style of dress, style of anything in which form or manner is conceived to be, in however slight a degree, expressive of taste or sentiment—if even this much of distinction still remains between what is called style and mere manner in the widest or loosest sense.

Style, in writing or speaking, may of course mean a bad style as well as a good style. Yet when the word stands alone, we always understand it in the latter sense—just as when we speak of expression in painting or in music we mean just or forcible expression. Thus, Swift has said, "Proper words in proper places make the true definition of a style." This, however, is merely to tell us, what is sufficiently obvious, that the art of expressing thought by language consists in two things: first, the selection of words; second, their collocation or arrangement. That to constitute a good style, both this selection and this collocation must be proper, there can be no doubt; the only question is, what constitutes propriety as to such matters. Style has been sometimes considered as nothing more than the image or outward expression of thought, as its produce or creation in the same sense in which it may be said that the impression upon the wax is the creation of the seal; and it has hence been assumed that all that is necessary for the ensuring of a style of any degree of excellence is the possession of a corresponding power of thought. But a little reflection will satisfy us that this is an insufficient explanation. Of two men equal in powers of mind, and equally in possession of a subject, nothing is more common than that the one should be able to expound it much more clearly and effectively than the other. Language is an instrument the use of which must be learned like that of any other instrument. Style is rather the vehicle than the mere expression of thought; and the thought may be present where the vehicle is wanting. To some extent, also, it may be said to be the dress of thought, or that which ornaments and sets off thought, not only by the added charms of sound, but by other powers which are inherent in words, and of which unexpressed thought knows nothing. As there are "thoughts that breathe," so there are "words that burn"—that by their associations excite impressions of the grand, the pathetic, or the humorous, whether they are addressed to the ear or merely to the eye. And great effects are also to be achieved by the arrangement of words, not only in the production of melody and cadence, but in a higher kind of gratification or excitement—as by the luminous disposition of all the parts of the sentence, by the presentment of every term at the place best fitted to bring out its whole import, by all the resources of what the grammarians call inversion, ellipsis, and other figures of speech; which, indeed, wherever they are properly used, are no deviations from natural syntax at all, but, on the contrary, the most natural forms that can be employed. For, while writing is an art, it is nevertheless most true that, like all the other arts the purpose of which is to give expression to mind, the guiding and controlling principle of its exercise, its life and being, as we may say, must ever be as exact and sympathetic a conformity as possible to the thoughts or emotions of the writer. Whatever more style is than the mere expression of thought, that much it must be at the least. A powerful thinker may not always be a powerful writer, but no man can be a powerful writer who is not a powerful thinker. Even the humblest quality of style, mere perspicuity, cannot be attained without a corresponding degree of clearness of thought. We sometimes meet with a perspicuity which is little more than grammatical, and hardly belongs to style at all; but even that implies distinct conceptions so far as they go—a limpid stream of thought, however little depth or spaciousness of intellect. And as for all higher attributes, it is manifest that they cannot be found in the style, if they do not exist in the mind of the writer. The only fountains from which a man's words can derive the animation of true passion, or poetry, or wit, must be his own head and heart.

The lowest kind of writing that deserves the name of a style at all (unless it is to be called a bad style) ought, as we have observed, to be perfectly perspicuous—that is to say, readily and completely intelligible in so far as the understanding of it depends merely upon a knowledge of the language. The subject may be a difficult one; but that is only a reason for more pains being bestowed to make the style clear and easy, by a lucid arrangement and the avoidance of all ambiguities of expression. But although this rule may be justly insisted upon where nothing beyond such perspicuity is desirable, it will not bear to be so rigidly enforced in regard to the higher kinds of style. Here some sacrifice even of perspicuity is at times to be submitted to, for the sake of appropriate effects which could not be otherwise attained. Æschylus, no doubt, might have made his chorusses, Pindar his odes, Tacitus his historic pictures, more easily comprehensible, better fitted for the use of such readers as would always run while they read, by greater diffuseness and dilution of style; but much more, certainly, would have been lost than gained by the attempt. What is to be desired in the highest kinds of writing, as in the highest creations of all the fine arts, is not perfect comprehensibility at a glance, but rather that fulness and profundity of meaning which can never be wholly comprehended, but supplies inexhaustibly something new to be seen and felt every time we return to the work.

In every cultivated language, however, the progress of style is decidedly towards more and more of first-sight intelligibility, in so far as that depends upon precision of phrase, and the use of words in certain limited meanings. This has been remarkably the history of the English language, at least for the last two hundred and fifty years, during which we have been fixing both our grammatical forms and our rules of syntax to an extent that would surprise most persons if the evidences of it were stated in detail. Whether all that has been done in this way has really improved the language,—whether it has been thereby rendered more expressive, more flexible, more fitted for the various ends which a language ought to subserve, may perhaps be questioned. The gain in point of precision may possibly be more than balanced by the loss both in ease and in variety of style.

In another respect, however, English prose eloquence has undergone a change of character in an opposite direction, by the greater infusion which it has received of a colloquial tone and phraseology within the last century and a half. Till towards the close of the 17th century, the language of books, except in the comic drama and other light compositions of a kindred character, generally preserved a formality of gait and manner which distinguished it nearly as much from living conversation as the critics have held that the language of verse should be distinguished from that of prose. Among the most eminent of the writers who first broke through this species of restraint were Cowley, in his Essays; Dryden, in his prefaces and other prose discourses; Sir William Temple; and the third Earl of Shaftesbury. The example set by them was followed by Swift, Addison, Steele, and their associates and imitators, till, in the earlier part of the last century, the colloquial ease and liveliness, which had thus become fashionable, threatened to degenerate into a slovenliness, or shambling fluency, alike without either elegance or precision. It must be admitted, that of all the writers of the second quarter of the 18th century, Lord Bolingbroke, whatever opinion may be entertained of his depth of thought or weight of matter, wrote the best style, at once the most flexible and idiomatic, and the purest, most refined, and most musical. But probably the writer who on the whole did most to restore measure and emphasis to our prose style was Johnson: his manner has not been much copied in all its peculiarities or in its entire character, but yet more or less of its influence may be detected in the style of nearly every one of the more remarkable writers who have subsequently appeared among us. At the same time, however, examples of altogether a different character were also producing their effects; and the rude vigour of Warburton, the *naiveté* of Sterne and Goldsmith, and, above all, the rapidity, variety, and imaginative splendour of Burke, have all operated powerfully in forming the greatest of our later writers. Finally, with all these influences have mingled and co-operated two others which have also been impulsive and generative to a considerable, though not both to the same, extent: on the one hand, the revived study of our old Elizabethan literature; on the other, the new life and spirit that has been put into literature, as into all things else, by the political and social convulsions of the last fifty years. These two influences, though thus apparently opposite in origin, have proved rather mutually assistant than contradictory.

Purity of style is more intimately connected with many apparently higher things than is commonly supposed. When it is considered, indeed, what the wrong use of a word springs from and implies, the mischief it is apt to occasion is easily understood. It is produced by a confusion of thought, which is propagated wherever the vicious mode of expression prevails, and which, besides the injury done in the particular case, helps generally to impair the habit and the faculty of clear and correct thinking. Yet words, for obvious reasons, have a strong tendency to shift their signification; if a language were to be merely spoken, and not written, this would be constantly taking place to a very great extent; the only thing that can check it, that can furnish a practically available standard of the language, is the employment of it in writing. Originally, indeed, the principles upon which it is written must be taken from its spoken form—from the *usus et norma loquendi;* but afterwards commonly the spoken language both will be and ought to be rather regulated and controlled by the written language. If it should continue to be otherwise, the language would not improve, but would degenerate towards barbarism; for there could be no progress in any other direction, in this or in anything else, where the comparative slovenliness and incorrectness of extemporaneous precipitation were allowed to carry it over the best efforts of deliberation and care.

STYLE, OLD AND NEW. By the Old Style is meant the mode of reckoning time anterior to the Gregorian reformation of the calendar; and by the New Style, that adopted since. The adoption of the reformation at different times by different countries renders it necessary to remember the difference of their reckonings, as follows:—

The reformation took place in 1582: from thence to the end of February, 1700, new style is *ten* days in advance of old style. Thus January 1 (O. S.) is January 11 (N.S.), and so on.

From and after March 1, 1700, to the end of February, 1800, new style is eleven days in advance of old style: thus January 1 (O. S.) is January 12 (N. S.).

The new style was adopted in England by 24 Geo. II. (1751), which enacted—1, that the year 1752 should begin on the 1st of January instead of the 25th of March, which was then the *legal* commencement; 2, that the 3rd day of September, 1752, should be called the 14th, or that the days from the 3rd to the 13th inclusive should have no nominal existence. Accordingly, the year 1751 had no January, February, nor March up to the 24th inclusive; and September wanted eleven complete days.

According to Sir Harris Nicolas, the new style was adopted as follows:—By Denmark, France, Holland, and most of the Low Countries (some towns excepted), most of Italy, Lorrain, Portugal, and Spain, in 1582; by German and Swiss Catholics in 1584; by Poland in 1586; by Hungary in 1587; by German and Swiss Protestants, and the remaining parts of Holland, &c., in 1700; by Tuscany in 1749 or 1751; and by Sweden in 1753. It is not yet adopted in Russia.

It was at one time sometimes the mode to express the date in both styles. We have an old letter written from France to Holland in 1619, as we should now call it, the date of which is Février $\frac{18}{28}$, $161\frac{8}{9}$. [Periods of Revolution.]

STYLOBATE. In its general meaning this term signifies any sort of basement upon which columns are placed to raise them above the level of the ground or floor; but in its technical meaning it is applied only to a continuous unbroken pedestal, upon which an entire range of columns stand—in contradistinction from *pedestals,* which are merely detached fragments of a stylobate placed beneath each column. The Greeks very rarely employed the stylobate, but placed their columns immediately upon the floor of the elevated platform of the gradini, or deep steps, which served as the basement of the temple, and which were generally continued on every side. [Grecian Architecture.] The Romans, on the contrary, broke up their stylobates into distinct blocks or pedestals placed beneath each column: and most followers of that or the Italian school have considered pedestals of that kind to be almost essential to an entire order, and have laid down proportions accordingly, which are in themselves exceedingly faulty, being much too high. At the best, columns upon detached pedestals always look as if placed upon stilts, and where such pedestals are as high as they are sometimes made, the columns seem to stand very insecurely, and the effect is very much like that of a round column immediately placed upon a dwarf square one.

STYPHNIC ACID. [Phenylic Group.]

STYPTICS (from στυπτικός, "astringent", agents which check the flow of the fluids, generally of blood, from a relaxed or ruptured vessel. They are a kind of astringent, and the principle of their mode of action has been already detailed. [Astringents.] The only point requiring notice here is to enforce the necessity of their prompt employment, as the natural disposition of the blood to coagulate becomes less and less as it continues to flow, till fainting be induced, and a cessation of the current results, after much injury is done to the system. The bleeding may be spontaneous, as is frequently the case with young persons, from whose nose blood frequently flows, even when perfectly quiet, but still more frequently when running or lifting some heavy weight, or it may be the consequence of a wound, such as a leech-bite, or of the extraction of a tooth, or caused by some cutting instrument. Those astringents are alone entitled to be called styptics which can be applied directly to the bleeding orifice; and of these some act chemically, others vitally, and others merely mechanically. Of chemical styptics, a saturated solution of alum, or sulphate of zinc, or creasote, are the best. Strong acetic acid acts both chemically and vitally. When blood continues to ooze from the socket of a tooth, it is a useful plan to plug it with a sponge-tent, which, as it expands, quite fills up the socket, and restrains the hæmorrhage.

A few drops of collodion upon a leech-bite, or the nap from a hat, or a spider's web, may be used.

STYRACIN. [Styrone.]

STYRACONE. [Styrone.]

STYRAX OFFICINALIS is the source of the officinal storax, although an article is occasionally vended under this name, which is obtained from the *Liquidambar styraciflua,* and perhaps other species of *Liquidambar,* yet in the London Pharmacopœia, it is said to be the produce of an unknown plant. Of genuine storax there are several varieties, and of those known to the ancients many are now altogether unascertainable, while of those mentioned by even recent writers several are very rare, and not of commercial importance. The tree grows in Greece and Asia Minor. Asiatic Turkey supplies whatever is met with in commerce. It is procured by incisions in the bark, or perhaps from the punctures of insects. What flows from these openings is a liquid resinous substance, which concretes into small tears, about the size of peas; these, aggregated into masses, constitute the *styrax albus,* which is of extreme rarity. Another form is that called *amygdaloides,* also of great rarity and extravagant price. It is sometimes termed *calamita vera.* The commercial article is of various degrees of purity and excellence. One kind is called *storax calamita vulgaris,* or *Scobs storacina.* This always contains more or less sawdust, mixed with variable quantities of resin. It is generally in large round cakes, of a brown colour, verging to red or black, with fragrant odour, brittle, and friable, but softens in the mouth, and has a bitter taste. It burns with a light flame. It is considered to be an artificial compound, prepared chiefly in Venice and Trieste. Liquid storax contains—volatile oil (styrol), a trace only; resin, both soft and hard, from 32 to 53 per cent. in different specimens; benzoic acid, from 1 to 2 per cent.; gum, 7 to 14; woody fibre, 20 to 27; ammonia, an inappreciable quantity; cinnamic acid and styracin.

Storax is stimulating in a degree dependent on its purity. For medical purposes it is directed to be purified by solution in alcohol, straining, and afterwards distilling off the spirit. The residuum is then used in a few preparations, such as tinctures and pills. It formerly entered into a multitude of compounds, but it might be altogether supplanted by benzoin. It is much used to form pastilles, and for fumigations. The bark is called *cortex thymiamatis,* or *cortex thuris,* from which, by boiling, liquid storax is procured, as well as from the *Liquidambar.* There is a storax from Bogota, but its source is unknown, though Geiger ascribes it to a styrax.

STYROL ($C_{16}H_8$). An essential oil existing in the gum resin, or balsam, of storax. [Balsams.] It is obtained on distilling a mixture of three parts of storax and one of carbonate of soda with water; and is purified by rectification after drying over chloride of calcium. It is colourless and limpid, has a persistent aromatic odour, and boils at 293° Fahr. It is isomeric with cinnamol or cinnamene, but is distinguished by being entirely solidified when heated suddenly to 400° Fahr. The solid is a polymeride of styrol and is termed *metastyrol,* or *draconyl,* the latter in allusion to another source, namely, dragon's blood resin (*Dracæna draco*).

Styrol is miscible in all proportions with alcohol or ether; is neutral, and has a density of 0·924. Sulphur and phosphorus are soluble in it. Nitric acid converts it into benzoic and nitrobenzoic acids; oily and resinous bodies being simultaneously formed. Chlorine and bromine form with styrol chloride and bromide of cinnamene.

Metastyrol is insoluble in water or alcohol, is only slightly soluble in ether, and has neither colour, odour, nor taste. It softens on the application of heat, and at a high temperature is reconverted into styrol. Nitric acid transforms it into *nitrometastyrol.*

STYRONE ($C_{18}H_{10}O_2 = \left.\begin{matrix}C_{18}H_9\\H\end{matrix}\right\}O_2$). *Cinnamic alcohol, Styracone, Peruvine, Cinnamyl-styrone* or *styracin,* or *metacinnamene* $\left(\left.\begin{matrix}C_{18}H_9\\C_{18}H_7O_2\end{matrix}\right\}O_2\right)$ is found in liquid storax and in balsam of Peru. On distilling either of the latter with strong caustic potash or soda, the styrone passes over along with water. On adding common salt to the water, a cream-like matter rises to the surface and gradually solidifies to an acicular mass of styrone. It melts when heated and boils at 482° Fahr. Its vapour has an agreeable odour resembling that of hyacinths: it rapidly attacks india-rubber. By peroxide of lead and caustic potash, or by chromic acid, styrone is oxidised to cinnamic acid. Under the influence of platinum black it is converted into the aldehyd of cinnamic alcohol $\left(\left.\begin{matrix}C_{18}H_7O_2\\H\end{matrix}\right\}\right)$ or hydride of cinnamyl, identical with the essential oil of cinnamon.

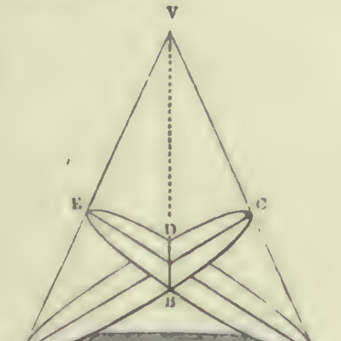
Styracin, or cinnamyl-styrone, is obviously polymeric with the hydride of cinnamyl just mentioned:—

$$\left.\begin{matrix}C_{18}H_9\\C_{18}H_7O_3\end{matrix}\right\}O_2 \quad = \quad 2\left(\left.\begin{matrix}C_{18}H_7O_2\\H\end{matrix}\right\}\right)$$

STYX (Στύξ or Στυγὸς ὕδωρ). In the ancient mythology the Styx was believed to be the principal river of the lower world, round which it flowed nine times. (Virg., 'Æn.,' vi. 439.) It was believed to be an arm of the river Oceanus, which flowed round our earth, and the river Cocytus was thought to be a branch of the Styx. When the gods of the ancients took a great oath, they always swore by the water of Styx, and awful punishment awaited him who swore falsely. The divinity of the river Styx was a nymph of the same name, daughter of Oceanus and Tethys, who dwelt at the entrance of the lower world in a spacious grotto supported by silver columns. (Hesiod, 'Theog.,' 778.)

SUB. A prefix applied in chemistry to a basic salt or to an oxide containing a less proportion of oxygen than a protoxide.

SUBCONTRARY. This word is particularly applied to the sections of a cone, in a manner which, without interfering with that application, would allow of its definition being generalised as follows:—When a figure or solid is symmetrical, so that equal lines or polygons can be drawn on two different sides, those equal lines or polygons may be called *subcontrary*. Thus, in Euclid, i. 5, the equal lines which are obliquely deflected from the two ends of the base of the isosceles triangle, are subcontrary. In a right cone every section has its subcontrary, except only the circle which generates the cone, and its parallels. Let V be the vertex of an oblique circular cone, and A B C D the circle on which it is described. Let the plane V A C be that which passes through the centre of the circle perpendicularly to its plane. Then the cone is exactly the same on one side of the plane V A C as on the other; and if a plane A G F be drawn through A perpendicular to the line which bisects the angle A V F, the section A G F is such that either half would take the place of the other, if it were to make a half revolution about A F. It is then an ellipse of which A F is one of the principal axes; and the middle point of A F, falling in the line which bisects A V F, is the centre. Consequently every section of this cone has a subcontrary section, except only those which are parallel to A G F. Hence the generating circle A B C D has a subcontrary circle E B F D, made by taking the line E F subcontrary to A C, and drawing through E F a plane perpendicular to the plane A V F. The angles V E F and V C A are equal, as also V A C and V F E.



In the limited use of the word subcontrary, no sections are considered in this light except the two circular sections of an oblique cone. Consequently, when subcontrary sections are mentioned, these circular sections are understood. The proofs given of the existence of these subcontrary sections usually conceal the fact of all cones described upon a circle being symmetrical when produced in every direction, and seem to make the existence of a second circular section a sort of accident of the circle, as if no other section had its subcontrary.

Since all parallel sections of a cone are similar, it follows that through every point of the surface two subcontrary circles can be drawn. The surfaces of the second order generally have the same property. [SURFACES OF THE SECOND ORDER.]

SUB-DOMINANT, in Music, the fourth of the key, mode, or scale. Thus, in the key of C, F is the sub-dominant.

SUBDUPLICATE, SUBTRIPLICATE. [RATIO.]

SUBERAMIDE. [SUBERIC ACID.]

SUBERANILIC ACID. [SUBERIC ACID.]

SUBERANILIDE. [SUBERIC ACID.]

SUBERIC ACID ($C_{16}H_{12}O_6 2HO$). An organic acid produced by treating rasped cork with diluted nitric acid; the cork is slowly dissolved, and a fatty substance is formed, which floats on the surface of the fluid. The solution is slowly evaporated till it thickens, and the residue is treated with about eight times its weight of water, by which an additional quantity of fatty matter separates. When the solution is filtered, suberic and oxalic acids separate, the former in the state of a white powder; this is to be saturated with ammonia, and the suberate of ammonia formed being decomposed by an acid, the suberic acid precipitates in the state of a white powder, which is to be washed with cold water. Suberic acid may also be obtained by treating margaric, oleic, or stearic acid with nitric acid. The properties of this substance are, that its acid powers are but feeble; it is very soluble in boiling water, and the greater part of it is deposited from the solution on cooling in the form of a white powder; it is soluble also in anhydrous alcohol; fuses at about 300°; and sublimes in acicular crystals.

The suberates are not an important class of salts; we shall therefore mention them briefly. Suberate of ammonia is soluble in water; the suberates of potash and soda are deliquescent, and fusible without decomposition: those of lime, baryta, strontia, magnesia, alumina, and manganese are more or less soluble; protosuberate of iron is a white precipitate; the persuberate is a brown one: the suberates of tin, zinc, mercury, and silver are white insoluble substances: that of cobalt is red, of copper blue-green, and uranium yellow.

By the distillation of suberic acid with excess of quicklime, a body termed *suberone* or *hydride of suberyl* ($C_{14}H_{12}O_2$) is produced. The following bodies are also derived from suberic acid:—

Suberamide	$C_{16}H_{16}N_2O_4$
Suberanilide	$C_{40}H_{24}N_2O_4$
Suberanilic Acid	$C_{28}H_{19}NO_6$

SUBERIC ETHER. [ETHYL.]

SUBERIN is a peculiar substance so named by Chevreul, as obtained from common cork, the epidermis of the *quercus suber*. When ten parts of cork have been treated with water, alcohol, ether, hydrochloric acid, potash, &c., there remain seven parts, which are suberin, possessing the following properties:—it is very inflammable; by distillation it yields water, a colourless oil, and afterwards a yellowish one, all of which are acid; then ammonia and a fatty crystallised substance are produced, and various gases are disengaged, while charcoal equal to one-fourth of the suberin remains in the retort. [CELLULOSE.]

SUBERONE. [SUBERIC ACID.]

SUBJECT, SUBJECTIVE. These words, with their correlatives Object and Objective, are now again restored to English philosophical language, through the medium of the German writers. The Subject is in philosophy invariably used to express the mind, soul, or personality of the thinker—the Ego. The Object is its correlative, and uniformly expresses anything or everything external to the mind; everything or anything distinct from it—the non-Ego. The universe itself, when considered as a unique existence, is an object to the thinker; and the very subject itself (the mind) can become an object, by being psychologically considered.

The distinction is most important. The exact distinction between the terms subject and object was first made by the schoolmen: for by the Greeks the word ὑποκείμενον was equivocally employed to express either the object of knowledge (the *materia circa quam*) or the subject of existence (the *materia in qua*). These correlatives, subject and object, correspond to the first most important distinction in philosophy, namely, the original antithesis of self and not-self. These terms, in their substantive and adjective forms, passed from the schools into the scientific language of philosophers.

SUBLIMATION, a chemical operation effected by the application of heat to certain bodies; it is essentially similar to distillation in principle, but differs from it in the nature of the substances to which it is applied. In distillation liquids are converted into vapour, and condensed into the same form by the cooling agency of water; whereas in sublimation solid bodies are vaporised, and afterwards reassume the solid state, in general merely by the cooling power of the air, without the assistance of cold water.

Sublimation is usually conducted in one vessel, the product being deposited in the upper part of it in a solid state, while the impurity remains in the lower. In small experimental researches a Florence flask answers perfectly well, and a good exemplification of the process is that produced by heating iodine in it: a purple vapour rises, which almost immediately condenses in small brilliant dark-coloured crystals in the upper part of the flask, the impurity remaining in the lower.

Sublimation is extensively employed, and for two different purposes; the simplest case is that of using it for purifying a substance, camphor for example, in which the pure camphor is vaporised, and condenses in the upper part of the vessel, while the impurities remain in the lower part.

In preparing corrosive sublimate and calomel, these substances are formed and sublimed by the same operation: in general large green-glass vessels, called *boltheads*, are used for calomel and corrosive sublimate; while for camphor very thin flint-glass vessels are used, which are called *bomboloes*, from the Italian *bombola*; in both cases a vessel is broken after each operation, to obtain the product. Among other substances procured by sublimation is benzoic acid, formerly called *flowers of benjamin*. This acid is sublimed in much larger vessels, and not usually made of glass; while the vapour of sulphur is condensed in a large chamber, or sulphur-house, and adheres to the walls in the form of a fine powder, known by the name of *sublimed sulphur*, or *flowers of sulphur*. [DISTILLATION.]

SUBLIME (Geometry). It may be worth while to state in few words, and to prevent a reader of the older mathematicians from imagining that they spoke rhapsodically, that the term *sublime geometry* was technical, meaning the higher parts of geometry, in which the infinitesimal calculus or something equivalent was employed.

SUBLIMITY has two significations: one, that of the quality or circumstance in objects, which raises the emotion named sublimity; the other, that of the emotion itself. The nature of the sublime, that is, those conditions of objects which invariably excite in us certain emotions, to which we give the common name of sublimity, is a subject of great interest and importance in psychology, and has always been a favourite subject of speculation. We shall briefly notice the more celebrated theories which have professed to embrace and explain all "those conditions which excite the emotions," and endeavour to point out their failures.

Longinus, whose work (Περὶ ὕψους) is the most ancient, treats only of the sublime in writing. His treatise was meant as a supplement to the work of Cæcilius on the 'Sublime,' in which he says Cæcilius brought a number of instances to show what is the sublime, as if every one did not know that well enough.

Burke's 'Inquiry into the Sublime and Beautiful' was the first attempt to give philosophical precision to our notions of the sublime. His theory is, that the essence of the sublime consists in terror operating either openly or latently; and the delight which is caused by this terror is referred to those principles of human nature which he calls "passions of self-preservation," and which turn on pain and danger. These passions "are simply painful when their causes immediately affect us; they are delightful when we have an idea of pain and danger, without being actually in such circumstances: this delight I have not called pleasure, because it turns on pain, and because it is different enough from any idea of positive pleasure—whatever excites this delight I call sublime." ('Inquiry,' part i., sect. 18.) "Whatever, therefore, is terrible, with regard to sight, is sublime too, whether this cause of terror be endued with greatness of dimensions or not." (Ibid., part ii., sect. 2.) Nothing can be more explicit than these two passages, nor more accurately exhibit the truth and error of his theory. The error is glaring in the second passage. Terror is often one feeling, exciting, in conjunction with other feelings, the emotion of sublimity, but not always. The stars are sublime, yet there is no terror in the emotion they excite. On the other hand there is a terror in a surgeon about to operate, or in a pedagogue about to flog—but no sublimity. The gallows is very terrible, but not at all sublime. Yet Burke was so chained down by his theory of terror being the ruling principle of the sublime, as to write—"There are many animals who, though far from being large, are yet capable of raising ideas of the sublime, because they are considered as objects of terror—as serpents and poisonous animals of all kinds." (Ibid., part ii., sect. 2.) Now, when a man asserts that a serpent is sublime, *because* it is terrible, it is evident that he uses the word sublime in a different sense from the rest of the world; otherwise we say a serpent is in no case sublime.

That the terrible is often a constituent of the sublime there can be no doubt, and Burke's error consists in seizing this occasional constituent, and declaring it to be the "ruling principle." And further, we must observe, that whenever a feeling of terror is found to be a constituent of the sublime, there will also invariably be found another feeling of security, correcting this terror. Thus, when we stand beneath a rock, the terror consists in a natural apprehension of its falling down and crushing us, which apprehension is instantly checked by our feeling of security and confidence of its not falling. If this feeling of security did not momently check the feeling of terror, the effect would be terror only, and not sublimity, and we should escape from it as swiftly as possible. So universal is this accompaniment of a feeling of security correcting the feeling of danger in every case of sublimity wherein terror is a constituent, that we are as much justified in asserting that "a feeling of security, either operating openly or latently, is the ruling principle of the sublime," as Burke was in his theory of terror. If terror had been found to be an invariable element of the sublime, the correct statement of the theory would have been—"The sublime is the effect of the concurrence of the two feelings of danger and security." But unfortunately there are many cases in which no feeling of danger can be found to exist. Infinity and eternity are sublime; but although, as he says, "infinity has a tendency to fill the mind with that sort of delightful horror which is the most genuine effect and truest test of the sublime," yet it does not necessarily fill the mind with horror; it may or may not, but in either case it is sublime. Helvetius says, "When God said, 'Let there be light,' and there was light: this image is sublime. But should such an image inspire fear? Yes; because it is necessarily associated in our minds with the idea of the Creator of such a prodigy; and being then seized in an involuntary manner with a dread of the author of light, we feel the sensation of a commencing terror." ('On Man,' vol. ii.) Now we contend that although fear would arise from such a train of thought, yet this train of thought is by no means a *necessary* sequence to the image—"God said, Let there be light, and there was light." It may or may not arise in the mind, but the sublimity produced by the image is not at all dependent upon it.

Lord Kames has a chapter in his 'Elements of Criticism,' on the sublime. He says, "A beautiful object *placed high*, appearing more agreeable than formerly, produces in the spectator a new emotion, termed the emotion of sublimity; and every other emotion *resembling* this emotion of elevation, is called by the same name." He has here the mere etymological notion of sublimity as something elevated, (See Dr. Parr's observations on the derivation of sublime from *supra limum*, in the Appendix to Dugald Stewart's 'Philos. Essays.') That there is little to be learnt from such an inquiry is evident.

Mr. Payne Knight, in his 'Analytical Inquiry into the Principles of Taste,' puts forth the theory that the sublime is the effect of the influence of *mental energy* exciting a sympathetic energy in the mind of the spectator or reader. The objections to this are the same as those to Burke's theory, namely, that it embraces a portion of the truth, which it would substitute for the whole truth. We have only to reflect an instant, and numberless instances of the sublime arise in which no mental energy is implied. Solitude, for example, is certainly sublime; so are infinity, eternity, Mont Blanc, &c. Mental energy is perhaps a more comprehensive formula for sublimity than terror, but it is still incomplete; and if one instance of sublimity can be quoted which does not contain the element asserted to be its 'ruling principle,' it is obvious that the theory must be erroneous.

Dugald Stewart's 'Essay on the Sublime' is entirely philological, and as such alone worthy of attention.

Dr. Thomas Brown combats the notion of a universal sublime, but avoids the real question altogether. All that is positive in his lecture on the subject is that the sublime and beautiful are not two distinct classes of emotions, but the same class, differing only in degree. "It is," says he, "as in the thermometric scale, by adding one portion of caloric after another, we arise at last, after no very long progress, from the cold of freezing to the heat at which water boils; though our feelings at these two points are as different as if they had arisen from causes that had no resemblance; certainly as different as our emotions of sublimity and beauty." ('Lectures on Philos. of Mind,' lvii.) Nothing can well be more erroneous than to take an analogy as a proof. Misled by his analogy, Dr. Brown has falsified the whole nature of the sublime, which, according to him, is but a larger or intenser form of the beautiful, whereas it differs essentially and antagonistically. He takes the instance of a stream gently gliding through fields rich with all the luxuriance of summer, overshadowed at times by the foliage that hangs over it from bank to bank. This is beautiful. He then traces it on to a majestic river, which flows on and deposits itself in the ocean. Here it becomes sublime. And this sublimity he thinks merely the last in the progressive series of emotions, as the boiling-point is the last in the progressive series of ascending heat. "If we were to contemplate this continued progress, we should have a series of emotions which might at each moment be similar to the preceding emotion, but which would become at last so different from our earliest feelings that we should scarcely think of them as feelings of one class." (Ibid.)

The answer to this is, that upon a similar principle of analogical reasoning, you might trace the "progressive series" of feelings which the man underwent from his earliest childhood; and when this series had conducted him to the gallows, you might say that his feelings at that moment were so different from his earliest feelings, that we should scarcely think of them as feelings of one class. Probably not. Nor should we, in our ethical philosophy, class the crimes which brought him to the gallows, with the innocence which commenced the "progressive series" of his emotions.

The whole of Dr. Brown's lecture on this subject is trivial or confused; and because he is unable to analyse the feeling itself, he boldly pronounces it not to be analysed. "It is the vain attempt to define what cannot be defined," he says, "that has led to all the errors and supposed mysteries in the theory of sublimity. Sublimity is not one emotion, but various emotions, that have a certain resemblance—the sublime in itself is nothing; or at least it is only a mere name, indicative of our feeling of the resemblance of certain affections of our mind, excited by objects material or mental, that agree perhaps in no other circumstance, but in that analogous undefinable emotion which they excite." We maintain, on the contrary, that sublimity is *one* emotion, not various similar emotions. It is itself complex, made up of various feelings; but it is one specific feeling, which preserves its characteristic throughout the various shades of difference in the objects which excite it.

Mr. Alison's 'Essays on the Principles of Taste' avoid the real question of sublimity, and the same must be said of his reviewer, Francis Jeffrey, who sums up his theory in these words: "The emotions which we experience from the contemplation of sublimity or beauty are not produced by any physical or intrinsic quality in the objects which we contemplate, but by the recollection or conception of *other* objects which are associated in our imaginations with those before us, and consequently suggested by their appearance, and which are interesting or affecting, on the common and familiar principle of being the natural objects of love, or of pity, or of fear, or veneration, or some other common and lively sensation of the mind." ('Edin. Rev.,' vol. xviii., and 'Essays.')

The first part of this passage is either a truism or an absurdity. A truism, if it be meant to state that as a mere sensation (without any respect to all the sentient being had previously undergone, and which that sensation would necessarily excite) an object in itself is not sublime (a truism however which Mr. Alison asserts to be the conclusion on which his speculations rest: chap. v., sec. 6); an absurdity, if it be meant to state that an object has no intrinsic quality capable of exciting that emotion. The size of a rock, for instance, is the condition of its sublimity; so with the cataract—make it a waterfall, and it ceases to be sublime; yet this difference of size is surely an intrinsic quality in the object which excites the emotion?

The fundamental principle of Mr. Alison's theory is "that all objects are beautiful or sublime which signify or suggest to us some simple emotion of love, pity, terror, or any other social or selfish affection of our nature; and that the beauty or sublimity which we ascribe to them consists entirely in the power they have acquired by association or otherwise, of reminding us of the proper objects of these familiar affections" (Ibid., and Alison's 'Essays,' i.)

This theory is in the highest degree vague. It does not discriminate what constitutes the sublime—it does not analyse that complex emotion, and draw forth its characteristic; and, moreover, in its sweeping generality includes much that it cannot apply to. All objects which excite terror are not beautiful nor sublime; neither are all objects which excite pity beautiful; and so of the rest. To discriminate those which are from those which are not, is impossible on this theory. To resolve the emotion of sublimity into association of ideas, is to say that this special emotion is resolvable into the general law of the human mind, but to avoid an analysis or characteristic statement of this special emotion altogether. It is saying that theft is a crime, and referrible to the general law of criminality, without once demarcating what constitutes theft as a crime, distinguished from murder as a crime. Attraction is the law which regulates the descent of an apple, and association of ideas in like manner is the law which regulates the operation of memory and the flights of imagination; yet as memory and imagination are distinct from the general law, as well as from each other, so also is the emotion of sublimity distinct from the emotion of hatred or beauty. Burke, Knight, Kames, and Price endeavoured to ascertain this distinction. Brown overlooked it, and Alison evades it. Had the special law of sublimity been found, and it was then attempted to be classed in its relation to the general law of the mind, the efforts of Alison and Jeffrey would have been of great importance; but in the meanwhile it was assumed.

It appears to us that the true method of attaining the knowledge of this special law of emotion, is the method of all psychological inquiries, namely, induction. Before attempting to detect the law which regulates it, we must collect all, or a vast number of instances of the sublime, and analysing the elements of each case, endeavour to discover *one* primal element which is invariably a constituent of the emotion, and without which all the other constituents would not be able to form that special emotion of sublimity.

In noticing the theories of former writers we have found their inductions imperfect; they have selected too few instances, and consequently when we came to select others, these theories were subverted by the mere statement of them. It was sufficient to disprove the theory of terror, to quote one instance wherein the terrible had no place, and the same with the theory of mental energy. But these theories, though incomplete, contain much that is true in their analyses.

In proposing a new theory, founded on a wider range of induction, we may observe that if any one instance of the universally acknowledged sublime can be found in which no such element (as the one we assert to be the ruling principle) be detected, then that single instance is a proof of the incompleteness of our theory, and a more extensive induction will be necessary.

It will be necessary for the sake of clearness to make use of purely mental distinctions in treating this subject, though they are liable to be misinterpreted as real distinctions; accordingly we divide the question of the sublime into three: 1. The material sublime—or the sublime of nature. 2. The moral sublime—or the sublime in human actions and ideas. 3. The emotion of sublimity, which these external things excite in us—or that feeling in the mind which gives to certain phenomena of nature, or deeds of man, the attribute of sublimity. Speaking *objectively*, the exciting cause of sublimity is vastness; speaking *subjectively*, the emotion excited is a sense of insignificance.

I. The material sublime. Examine every case of material sublimity, and the most primitive fact will be found to be vastness; whatever feelings may simultaneously concur, this of vastness is invariable. Mere vastness is sublime. Vastness either of form or of power. Hampstead Heath is not sublime, but Mont Blanc is. The Thames is not sublime, but the ocean is. Solitude is sublime—because it is vast, that is, indefinite. But solitude in a room or garden is not sublime. A cataract is sublime, but not a waterfall, yet the one is only larger than the other. Longinus has remarked that the light of a small fire produces no emotion, but that the boiling furnaces of Ætna, pouring out whole rivers of liquid flame, is sublime. Burke remarks that all general privations are sublime because terrible, such as vacuity, darkness, solitude, and silence. But they are sublime because vast, not because terrible; for they are not necessarily terrible, and they are necessarily vast, indefinite.

These instances are sufficient to illustrate the principle. It will be observed that there are some which seem more naturally to derive their sublimity from terror than from vastness, as Ætna for example. But our object was to show that vastness was always a constituent, even when other emotions came into play; and as we have already seen instances where terror does not form one constituent, and that when it does form one, it is still accompanied by vastness, so we prove thereby that vastness is the more general fact. Vastness is sublime as vastness; but terror is not sublime as terror. The difference between a shower and a storm is purely quantitative, yet the storm alone is sublime.

II. The Moral sublime. It is obvious that the moral sublime must differ from the material sublime in proportion as mind and matter differ. Hence vastness, which in the external world is superficial (*in extenso*), in the moral world becomes intense (*in intenso*). Intensity of will equals vastness of form or power. Mere intensity is sufficient to produce the sublime. Œdipus is sublime. Lear, who appeals to the heavens, "for they are old" like him, is sublime, from the very intensity of his sufferings and his passions. Lady Macbeth is sublime from the intensity of her will, which crushes every female feeling for the attainment of her object. Scævola with his hand in the burning coals exhibits an intensity of will which is sublime. It will be difficult to find terror as an element of these cases of the sublime. Mr. Knight's "mental energy" has here more truth; but though a satisfactory explanation of the moral sublime, yet it will not apply to the material sublime. The intensity of power as a source of the moral sublime, has been adopted by Mr. R. Blakey, in his 'History of the Philosophy of Mind,' 1848.

Such appear to us to be the objective qualities of sublimity, but the peculiar emotion they excite has hitherto been thought undefinable: we shall nevertheless attempt it.

III. The emotion of sublimity. As in considering objectively every case of material or moral sublimity, we found as the primary and invariable fact vastness or intensity, so in considering subjectively every case of sublimity as an emotion, we shall find the primary and invariable fact to be a sense of our own insignificance; of our inferiority to the object, or to the will which prompted the deed; and this sense of inferiority has guided mankind in the employment of a word expressing elevation for sublimity. Mere vastness excites this emotion by exciting a corresponding sense of our smallness. Mere intensity excites this emotion by exciting a corresponding sense of our feebleness. Vary the objects—vary the emotions as you may, there will invariably be this one feeling of comparative insignificance. Take as an example the sublime words of Scripture, "I am the High and the Lofty One, who inhabiteth eternity." Nothing can exceed the grandeur of that idea, and he who conceives it conceives also, at the same time, the corresponding idea of his own small and finite nature. In the violent dashing of a cataract, in the roar of the ocean, in the violence of the storm, or in the majestic quiet of Mont Blanc preserving its calm amidst all the storms that play around it, or in the concentrated will of a Scævola, Horace, Brutus, or Œdipus, in all these cases we are moved by a vivid feeling of some greater power than our own, or some will more capable of suffering, more vast in its strength than our feeble vacillating will. It is from this reason that an imaginative mind experiences more emotions of sublimity than another. In proportion as we comprehend the majesty of nature, or the amount of self-sacrifice in an heroic action, we comprehend our own inferiority to them.

In conclusion we may thus sum up our theory. The invariable condition of sublimity in objects, either material or moral, is vastness or intensity. The invariable condition of the emotion of sublimity—that which distinguishes this emotion from every other emotion—is a comprehension of this vastness with a simultaneous feeling of our own comparative insignificance, together with a concomitant sense of present security from any danger which might result from this superior power. The antithesis to the emotion of sublimity is the emotion of contempt.

SUBMARINE DESCENT. [DIVING BELL.]

SUB-MULTIPLE. [ALIQUOT PART.]

SUBORNATION OF PERJURY. [PERJURY.]

SUBPŒNA. [WITNESS.]

SUBPŒNA, WRIT OF, IN PLEADING. [PLEADING IN EQUITY.]

SUBSALTS. [SALTS; CHEMICAL NOMENCLATURE, *Nomenclatu Salts.*]

SUBSIDIARY. A quantity or symbol is so called whe is not essentially a part of a problem, but is introduced to help in e solution. The term is particularly applied to angles, since the gonometrical tables give a great power over their management, ich causes their frequent introduction, even in problems in whic here is no question of angular quantity. For example, suppose it required to calculate $ax+b\sqrt{(1-x^2)}$, where $a = {\cdot}29164$, $b = 3{\cdot}0$ 8, $x = {\cdot}11316$. Assume

$x = \cos\theta$, $a = r\cos\phi$, $b = r\sin\phi$, which gives θ from the tables, and ϕ and r from the tables and from

$$\tan\phi = \frac{b}{a},\ r = \frac{a}{\cos\phi}.$$

The quantity to be calculated is

$$r\cos\phi\cos\theta + r\sin\phi\sin\theta, \text{ or } r\cos(\phi-\theta),$$

$$\text{or} \qquad \frac{a\cos(\phi-\theta)}{\cos\phi},$$

and the final result is found from the tables in much less time than $ax + b\sqrt{(1-x^2)}$ could be calculated by ordinary means. There is, of course, no rule for the most convenient introduction of subsidiary angles: every case must be treated according to the circumstances it presents.

SUBSIDY, from *subsidium*, a Latin word signifying aid or assistance. "Subsidies," says Lord Coke, "were anciently called auxilia, aides, granted by act of parliament upon need and necessity; as also for that originally and principally they were granted for the defence of the realm and the safe keeping of the seas," &c. The word used in its general sense was applied to aids of every description; these were of two kinds, one perpetual, the other temporary. Those which were perpetual were the ancient or grand customs, the new or petty customs, and the custom on broad-cloth. The temporary included tonnage and poundage; a rate of four shillings in the pound on lands, and two shillings and eightpence on goods, aliens paying double; and the fifteenths or tenths, &c., of moveable goods. The limited sense, which is also the more common sense, of the word subsidy, attaches only to the rate on lands and goods.

The grand customs were duties paid on the exportation of wool, sheepskins, and leather, at the rate of, for every sack of wool weighing thirty-six stone, half a mark, or six shillings and eightpence; for every three hundred sheepskins, half a mark; for a last of leather, a mark, or thirteen shillings and fourpence. The petty customs were payable by merchant strangers only, and consisted of an excess of one half over and above the grand customs payable by native merchants. The custom on broadcloth was first given to the king in the 21st year of Edw. III., to indemnify him for the loss he incurred in consequence of the practice, then beginning to prevail, of making up the wool into cloth in this country previous to its exportation. There were also two species of customs payable on wines: one called butlerage, payable by foreigners importing wines, at the rate of two shillings for every tun of wine; the other, called prisage, payable by natives at the rate of, for every vessel importing ten tuns of wine, one tun; for every vessel importing twenty or upwards, two tuns; taken one tun from before, the other from behind the mast. This was compounded for by the payment of 20*s.* for each tun to which the king was entitled.

The origin of these customs seems uncertain; Lord Coke is very anxious to prove that they were in the first instance established by the common consent of the realm in parliament assembled. In support of this he cites Philip de Comines, lib. v., fo. 233. Before and during Lord Coke's time, as well as immediately after it, the origin and nature of this kind of subsidy were most fully and ably discussed. Besides what may be called the private property of the crown, the king had a right to require contributions from the inhabitants of particular districts towards the expense of repairing bridges and the walls of towns, which contributions were called pontage and murage; and to grant by charter to any city the right to levy tolls upon all vendible things coming into the town. There were also other sources of revenue, the temporalities of vacant bishoprics, the forfeitures arising from felonies, &c. In the earlier periods these seem to have been considered sufficient to maintain the royal state, the courts of justice, &c., and also the ordinary expenses of any wars in which the king might be engaged. In the sixth year of Richard II., the commons petitioned the king that he would live upon his own revenues, and that wards, marriages, releases, escheats, forfeitures, and other profits of the crown might be kept to be spent upon the wars for the defence of the kingdom. In addition however to these duties of defending the kingdom by foreign wars, the king was bound to protect the merchants at sea from pirates, &c., and for this purpose a practice prevailed twice in the year "to scour the narrow seas." To defray the expenses of the royal navy, the king collected at the ports of his kingdom certain sums upon all merchandise imported or exported. These sums were called customs, a word which in itself indicates the earliness and uncertainty of their origin. In process of time however, the ordinary sources of the king's revenue being continually diminished by the alienation of crown lands, &c., while the expenses of the crown were increased, the kings imposed of
[illegible] own authority such sums as varied from the original amount
car[illegible]d, and were complained of as unreasonable by the people. The
against [illegible]liamentary history is full of remonstrances and petitions
There was [illegible]ous and unaccustomed impositions, maltolts (evil tolls), &c.
might pay [illegible]stance also of a petition by the merchants that they
Ultimately the [illegible] but be allowed to protect their ships themselves.
of the collection of [illegible] were driven by their necessities, the difficulties
position, to have recou[illegible]gular duties, and the circumstances of their
to be collected as customs [illegible] to parliament to fix and authorise the sums
[illegible] The first statute on the subject occurs in the third year of the reign of Edward I., when the ancient or grand customs were fixed at the sums already stated.

It is observable that in no instance was the right of the king to collect some duties disputed; all that is complained of is the excess and unreasonableness of the sum recently imposed. Many statutes occur on the subject, but their provisions were frequently violated, down to the reigns of Elizabeth and the Stuarts. In these later times, however, such infringements were not passed over lightly. In the reign of James I. the question as to the right of the king to increase the customs upon merchandise, without assent of parliament, was raised on the occasion of his imposing 5*s.* per cwt. on currants. The court of exchequer decided that the king had such right, on the grounds, 1st, that his extraordinary and absolute prerogative was not bound by the statutes restraining him from increasing the customs without assent in parliament; 2nd, because the extra duty "was not a burden to the commonwealth, but to delicate mouths." This decision however raised great discussion in parliament, who pronounced it to be illegal. The writs for ship-money in the time of Charles I. created a similar ferment, and notwithstanding the petition of rights, the question cannot be said to have been entirely set at rest till up to the period of the Revolution.

The petty customs were originally founded on a bargain between the foreign merchants and king Edward I., by which they agreed to pay him the amount of them, in consideration of certain privileges granted them, and a release to them of all other prises and takings. Butlerage has the same origin, but is perhaps of an earlier date. Prisage is stated by Lord Coke himself to be due to the king by prescription, and the right of the king to it seems to have stood upon that alone; that right must have been one of inheritance, since by royal charters it was granted to the city of London and to the Cinque Ports for ever.

Tunnage and poundage was a duty varying in amount at different times from 1*s.* 6*d.* to 3*s.* upon every tun of wine, and from 6*d.* to a 1*s.* upon every pound sterling of merchandise coming into the kingdom. The object in granting it was said to be, that the king might have money ready in case of a sudden occasion demanding it for the defence of the realm or the guarding of the sea. In the course of the argument in the case of ship-money in 13 Charles I., the king's duties are said to amount to 300,000*l.* This probably was the aggregate of the customs and tunnage and prisage.

The taxes called tenths and fifteenths were the tenth or fifteenth part of the value of moveable goods. Other portions, such as the fifth, eighth, eleventh part, were sometimes, but rarely, also levied. These taxes seem to have had a parliamentary origin. Henry III. received a fifteenth in return for granting Magna Charta and the Charta de Foresta. In the earlier periods never more than one subsidy and two fifteenths were granted. About the time of the expectation of the Armada (31 Eliz.), a double subsidy and four fifteenths were granted. Subsidies and fifteenths were originally assessed upon each individual, but subsequently to the 8 Edward III., when a taxation was made upon all the towns, cities, and boroughs, by commissioners, the fifteenth became a sum certain, being the fifteenth part of their then existing value. After the fifteenth was granted by parliament, the inhabitants rated themselves. The subsidy, never having been thus fixed, continued uncertain, and was levied upon each person in respect of his lands and goods. But it appears that a person paid only in the county in which he lived, even though he possessed property in other counties. Certain it is that the subsidy continually decreased in amount. In the eighth year of the reign of Elizabeth it amounted to 120,000*l.*, in the 40th to 78,000*l.* only. Lord Coke estimates a subsidy (probably in the reign of James I. or Charles I.) at 70,000*l.*; the subsidy raised by the clergy, which was distinct from that of the laity, at 20,000*l.*; a fifteenth at about 29,000*l.* Eventually the subsidy was abolished, and a land tax substituted for it.

(2 *Inst.*; 4 *Inst.*; 'Bate's Case,' &c., 2 *State Trials*, 371, ed. 1809; 'The Case of Ship Money,' 3 *State Trials*, 826, ed. 1809; Venn's *Abrt.*, tit. 'Prerogative;' Comyn's *Dig.*, tit. 'Parliament,' 'Prerogative,') [CUSTOMS.]

SUBSTANCE. In general usage substance means a solid. In philosophical speculations it has undergone the fate of most general terms, and has been tortured into all possible shades of meaning. In physical speculations it has usually been taken as an equivalent to matter; but in metaphysical speculations its meaning, as sanctioned by the highest authorities, has remained true to its etymon (*sub-stans*, that which *stands under* phenomena). This meaning will be rendered intelligible by the notion of some Hindu philosophers, who supposed the world to rest on the back of an elephant, and that the elephant stood on the back of a tortoise; what supported the tortoise, they omitted to explain. In adopting their theory, we may add that *that* which the tortoise stood upon was substance.

As we know that all phenomena must depend upon noumena, of which they are only the manifestation; or, to use the language of the schoolmen, as all accidents must be accidents of *something*, and must depend on that something for their existence, so in pushing our analysis to its limit, we must finally arrive at a point to which we can give no antecedent, which we are forced to assume as final, and as standing under or supporting the whole, and this we call substance. It is the fundamental fact of all existence. We can never know it, for we only know phenomena, which are its appearances. We can never conceive it, for the first attempt to conceive it brings it within the sphere of our ideas, which are only those of phenomena. We can never imagine it; but we are compelled to assume it. It is to us a logical fact, not a noumenal one. Necessary as the basis of all speculation, as the "point" in mathematics, but, like the point, for ever a mere logical distinction. It is needful for all men to know that this substance is, with respect to the mind, a merely logical distinction from its attributes; and it is needful also to know that as the mind can never transcend the sphere of its action, and consequently never know more than the attributes, all that it can predicate of substance must be false, for substance is to it a mere negation; if it would affirm anything of substance, it must inevitably affirm it by its attributes, which it alone can know positively.

It is from inattention to this latter fact that metaphysicians have blundered and misunderstood each other so constantly. You cannot conceive a point which has neither length nor breadth; you must assume it. You cannot conceive substance shorn of its attributes, because those attributes are the sole staple of your conceptions; but you must assume it. Analyse as you will, you can never get beyond a vague and negative conception of a certain substratum, which, whenever you attempt to realise it, you must invest with attributes. Glass is a substance, at least is called so in common language. Analyse it, and you will find that it is no substance—that it is merely the co-existence of flint and alkali. Your substance then has vanished with the analysis. It was found to be flint *and* alkali, nothing more; no distinct element, no *substratum* was discovered. Where then was your glass substance? The glass was a mere mode of existence of two particles of flint and alkali; it was in itself nothing, it had no existence apart from those particles, it had no *substratum*. Analyse the flint in the same way, and you will find the flint to be in itself no substance, but a mode of existence of some other particles. And yet the mind refuses to admit that this analysis could be so continued ad infinitum, thus reducing everything to mere phenomena; it is impelled to stop somewhere, and to ask, "attributes of what?" and there where it stops it recognises substance. Hence Spinoza's definition of substance being existence itself.

Fichte, the most scientific expositor of idealism, has denied all substance except that of the Ego, and he says, "Attributes synthetically united give substance, and substance analysed gives but attributes; a continued substratum, a supporter of attributes is an impossible conception." ('Wissenschaftslehre.') Granted an impossible conception, but not therefore an impossible fact. Fichte assumes that the subjective conception—the idea—is the complete correlation and adequate comprehension of the whole objective fact; and if this point be admitted, his system is irrefutable, for attributes being obviously mental conditions, and as beyond them we are conscious of nothing, so nothing but what they affirm can exist. Interrogate consciousness, and you will get no answer that will apply to a substance. It knows only attributes.

If we dissent from these conclusions, and maintain that there is substance apart from its attributes (though we insist on this distinction being purely logical), it is because the idealists have not proved the fundamental position on which all such speculations rest, namely, the truth of the correlation between the conception and the object, so that the one should be taken as the entire expression of the other.

In our analysis of substance it is impossible to get beyond attributes; and therefore, subjectively speaking, substance is nothing more than the synthesis of attributes: but does this entitle us to assume that it is equally the case objectively? Not until the subject has been proved to be the complete expression of the object.

But the truth is, attributes themselves are but the conditions excited in us by objects. The Ego acted on by the non-Ego undergoes certain affections: these mental affections are variously extension, colour, weight, hardness, &c., and these are all the effects of the action of the non-Ego upon the Ego, and as a consequence these are all we know, and all we know of the non-Ego. To call substance therefore the synthesis of attributes, is to say that in the synthesis of our mental affections is contained all that *constitutes* the non-Ego, instead of saying that in the synthesis of our mental affections is contained all we can positively *know* of the non-Ego; it is saying that we include all existence, and that beyond our conceptions nothing exists; it is taking the human mind as the measure of the universe.

We maintain therefore, that inasmuch as what we call attributes are not vague abstractions, but positive effects of matter acting on the sensory (and we assume the existence of matter because Idealism has failed in disproving it); so there must be substance or cause to produce those effects; and although we can only know these effects and *by* these effects, yet we are necessitated to assume an inconceivable cause or substance. We do not know this substance: we only know what sensations it excites in us.

The stronghold of Idealism is consciousness. In consciousness there is nothing but transformations of itself—no substance, no external world is given; it knows, it feels, it is conscious of nothing but itself. But consciousness is equally the stronghold of realism; for we are as conscious that what we call substance, or the world, is not ourselves, and does not depend upon us, and is a distinct existence, as we are of our own existence. Hence the universality of the belief of an external world—hence the impossibility of the idealists' conceiving for an instant the non-existence of substance.

In conclusion we may observe, that substance is the unknown, unknowable substratum on which rests all that we experience of the external world; it is the hidden noumenon whose manifestations as represented in perception we call matter and the phenomena of matter, and of which every positive predicate must necessarily be false, and consequently all inquiry into its nature baseless.

SUBSTITUTION. One of the most important methods of forming chemical substances, and of ascertaining the constitution of compounds, is that known as substitution. The term substitution, as thus chemically applied, simply means the replacement of a body already in combination by another body not in combination, and of course includes all processes of single or double decomposition. Thus, in a compound A B, substitution of B for C may be effected by simply bringing C into contact with A B, the new compound A C being produced: this case of substitution is one very frequently performed in chemical research and manufacture, and is known as single decomposition or single elective affinity. Again, in a compound A B, substitution of B by C may be effected by bringing a compound C D, containing C, into contact with A B, thus producing the required substance A C; this method of substitution is fully as important as the other just mentioned, and is known as double decomposition or double elective affinity, because there are, so to speak, two elections or choices going on, namely, A for C, and B for D, whereas in the former illustration only one occurs. By using varying amounts of a substituting body, C_x, and bringing forces other than the chemical to his aid, the chemist can sometimes produce several distinct compounds of the same bodies, thus :—$AB_x + C_2 = AB_{x-2}C_2 + B_2$ or $AB_5 + C_5 = AC_5 + B_5$. Frequently the body substituted unites with one half of the substituting body, thus :—$AB + C_2 = AC + BC$.

Although, strictly speaking, single and double decomposition are processes of substitution, it is found convenient to restrict the term substitution to cases in which organic compounds are being operated on, while the phrases single decomposition and double decomposition are conventionally applied to inorganic transformations only. [CHEMICAL AFFINITY.]

The simplest examples of substitution occur when chlorine, or either of its analogues, bromine and iodine, is made to act upon an organic compound. Thus chloride of ethyl (C_4H_5, Cl), by the action of chlorine suffers replacement of its hydrogen by chlorine; hydrochloric acid being formed and the following bodies successively produced :—

Chloride of chlorethyl	. . . . .	$C_4\left\{\begin{matrix}H_4\\Cl\end{matrix}\right\}Cl$
" bichlor-ethyl	. . . . .	$C_4\left\{\begin{matrix}H_3\\Cl_2\end{matrix}\right\}Cl$
" trichlor-ethyl	. . . .	$C_4\left\{\begin{matrix}H_2\\Cl_3\end{matrix}\right\}Cl$
" quadrichlor-ethyl	. . . .	$C_4\left\{\begin{matrix}H\\Cl_4\end{matrix}\right\}Cl$
" perchlor-ethyl or sesquichloride of carbon	. . . .	C_4Cl_5Cl

The constitution or construction of the original compound from which such a series of derivatives is obtained seems to alter but little. As might be expected from the nature of the elements, the boiling point of a body containing chlorine in the place of hydrogen is higher in direct proportion to the amount of hydrogen replaced. Specific gravity also undergoes relative increase; while vapour volume remains constant. Only when complete substitution of one body by another has taken place does the molecular arrangement of the original compound appear to give way.

The substitution of chlorine for oxygen, and of oxygen by hydrogen, is frequently performed by chemists. Peroxide of nitrogen (NO_4), also, may be introduced into organic compounds by acting upon them, under certain conditions, with nitric acid; in these cases hydrogen is displaced and forms water with the fifth equivalent of oxygen, while peroxide of nitrogen takes the place of the hydrogen.

SUBSTITUTION, a very common algebraical process, being, as its name imports, the substituting for any quantity another which is equal to it.

A method of approximation, which is frequently used and of great importance, has obtained the name of *successive substitution*. Let any equation be reduced to the form

$$x = a + e\phi x,$$

where e is less than unity, and ϕx a function of x. If we make $x = a$, the error thereby committed is less than ϕx, being $e\phi x$, in which e is less than unity. Take this value $x = a$, and substitute it on the second side, giving $x = a + e\phi a$: this value is nearer than the last in most cases, for it should be

$$\begin{aligned} x &= a + e\phi\,(a + e\phi x) \\ &= a + e\phi a + e^2\phi' a.\ \phi x \text{ nearly,} \end{aligned}$$

where $\phi' a$ is the differential coefficient of ϕa. The last error was $e\phi x$, and the present error is less, if $e\phi' a$ be less than unity. Generally, if for x we write $a+p$, and if p be erroneous by a quantity of the order e^n, we shall have, by one more substitution,

$$x = a + e\phi(a+p).$$

Now the error of $\phi(a+p)$ will be of the order e^n, and that of $e\phi(a+p)$ of the order e^{n+1}. There is then a continual approximation to the value of x.

Beginning with $x = a + e\phi a$, in which the error is of the order e^2, we have

$$x = a + e\phi(a + e\phi a),$$

in which the error is of the third order. Rejecting terms of the third order, we have

$$x = a + e\phi a + e^2\phi a\phi' a.$$

Substitute this again, and we have

$$x = a + e\phi\left\{a + e\phi a + e^2\phi a\phi' a\right\},$$

in which the error is of the fourth order. Rejecting terms of the fourth order,

$$x = a + e\phi a + e^2\phi a\phi' a + e^3\left\{ (\phi' a)^2\phi a + \frac{\phi'' a}{2}(\phi a)^2 \right\}$$

and so on: the development being made by TAYLOR'S THEOREM. This would lead in effect to the celebrated theorem of Lagrange; but the actual method of substitution is sometimes preferable.

SUBTANGENT, SUBNORMAL. [TANGENT.]

SUBTENSE, means any line, angle, &c., opposite to or *subtending* a line or angle spoken of. Thus the chord of a circle is the subtense of the arc and of the angle at the centre. The term is now not much used.

SUBTRACTION, SUBTRAHEND, MINUEND. The process of subtraction is the removal of a part equal to the less from the greater. The quantity to be diminished (*minuendum*) was called the *minuend;* the quantity to be withdrawn (*subtrahendum*), the *subtrahend;* and the remaining part, the *remainder*. The terms subtrahend and minuend are almost out of use, though often very convenient.

The operation of subtraction is often described in a way which might be practised, but is not; and the explanation of the possible mode applied to the actual mode makes confusion. It is obvious enough that if parts of A be subtracted severally from greater parts of B, the remainders put together make up the whole remainder. Thus, 24 can easily be taken from 76, for 7 tens exceeds 2 tens by 5 tens, and 6 exceeds 4 by 2, so that 52 is the remainder required. But when we come to take 48 from 93, the preceding mode of partition is useless. To remedy this, it is proposed in the explanation to *borrow* 1 of the 9 tens in 94, and to put it on to the 4: then 8 from 18 leaves 5. Now take the 4 tens of 48, and subtract from the *remaining* 8 tens of 93, and 4 tens are left: the answer then is 45. The process would be as follows:—

93	8 from 3, impossible; borrow a ten from 90; 8 from 13 leaves
48	5. Take 4 tens from the remaining 8 tens, one of the 9
—	tens having been borrowed, and 4 tens remain.
45	

This process is actually used on the Continent; but with us, as all the world knows, there is a different process, as follows:—

93	8 from 3 impossible: take 8 from 13, and 5 remains. *Carry**
48	one to 4, giving 5, and subtract 5 tens from 9 tens, giving 4
—	tens.
45	

There is quite a different principle in this process, which is as follows:—If two numbers be equally increased or equally diminished, the difference remains the same. Having arbitrarily increased the 3 in the upper line by 10, the lower line must be somewhere or other increased by 10, in order to keep the difference (which is all that is wanted) unaltered.

The object in view is attained by increasing the upper line by ten *units*, and the lower line by one *ten*.

For further detail, see COMPUTATION.

SUCCESSION. This is a legal term derived from the Roman "Successio," which signifies a coming into the place of another, and Successor is he who comes into such place.

The Roman term signifies a coming into the place of another so as to have the same rights and obligations with respect to property which that other had. There might be successio either by coming into the place of a person living, or by becoming the successor of one who was dead. Gaius (iii. 77, &c.) gives instances of successio in the case of persons living, one instance of which is the Bonorum Cessio according to the Lex Julia. Succession was again either Universal or Singular. The instances of universal succession (per universitatem) which Gaius (ii. 97) enumerates, are the being made a person's heres, getting the possessio of the bona of another, buying all a man's property, adopting a person by adrogatio, and admitting a woman into the manus as a wife; in all of which cases all the property of the several persons enumerated passed at once to the person who was made heres, or got the bonorum possessio, or bought the whole property, or adopted another by adrogation, or married the woman. An instance of singular succession is the taking of a legacy under a man's will.

The term Succession is used in our language. We speak of the succession to the crown or the regal dignity, and the term implies that the successor in all things represents the predecessor. Indeed, the king, as a political person, never dies, and upon the natural death of a king the heir immediately succeeds. The English heir-at-law takes the descendible lands of his ancestor as universal successor; and the executor takes the chattels real and other personal property of his testator as universal successor. The general assignee or assignees of a bankrupt or insolvent take by universal succession.

Blackstone says that "corporations aggregate consist of many persons united together into one society, and are kept up by a perpetual succession of members, so as to continue for ever." It is true that when members of a corporate body die, others are appointed to fill up their places, but they do not succeed to the others in the Roman sense of succession—they simply become members of the corporation. But it has been established in some cases that the use of the word "successors" implies that the legislature meant to establish a corporation; and yet it is certain that a feoffment of land to a corporation aggregate without the word "successors" is a valid grant. In a feoffment to a corporation sole the word "successors" is necessary. The succession in the case of a corporation sole follows the nature of the Roman succession. In the case of a corporation aggregate there is no succession, and the rule that a corporation may be established by the use of the word "successors" in a statute is founded on an erroneous understanding of the term "successors."

SUCCESSION DUTIES. For many years persons succeeding to personal property (including leaseholds) whether they took by will as executors or legatees, or merely as administrators or next of kin, were charged with *Legacy Duties*, which were payable over and above the stamp duty, then and still levied in the first instance, on the grant of probate or letters of administration, according to the estimated sworn value of the personal property of the deceased. The legacy duty was chargeable after the estate of the deceased had been realised and administered, on the property distributed among the legatees or next of kin, as the case might be; and varied in amount, according to the consanguinity of the next of kin, or the absence of any relationship between the legatee and the testator. The exemption of real estate from this species of taxation long complained of as creating an undue preference in favour of the holders of landed property, has at last been removed. By the Succession Duties Act, 1853, duties are imposed on every succession to property, whether real or personal, according to the value and the relationship of the parties to the predecessor. Where the successor is the lineal issue or lineal ancestor of the predecessor, 1*l*. per cent.; where a brother or sister, or a descendant of a brother or sister, 3*l*. per cent.; where a brother or sister of the father or mother, or a descendant of the brother or sister of the father or mother of the predecessor, 5*l*. per cent.; where a brother or sister of the grandfather or grandmother, or a descendant of the brother or sister of the grandfather or grandmother of the predecessor, 6*l*. per cent.; and where the successor is in any other degree of collateral consanguinity to the predecessor, or is a stranger in blood to him, 10*l*. per cent. The value of the succession, if it be to real property, is ascertained by considering the interest of the successor as of the value of an annuity equal to the annual value of the property, estimated as the act directs; and the duty may be paid by eight equal half-yearly instalments, or at once, according to the wish of the party liable thereto.

SUCCESSIVE SUBSTITUTION. [SUBSTITUTION.]

SUCCINAMIC ACID. [SUCCINIC GROUP.]

SUCCINAMIDE. [SUCCINIC GROUP.]

SUCCINAMILIC ACID. [SUCCINIC GROUP.]

SUCCINALIDE. [SUCCINIC GROUP.]

SUCCINANILE. [SUCCINIC GROUP.]

SUCCINIC ACID. [SUCCINIC GROUP.]

SUCCINIC ETHER. [ETHYL.]

SUCCINIC GROUP. The generic name of succinic acid and its derivatives.

Succinic acid ($2HO, C_8H_4O_6$) exists naturally in AMBER (*succinum*), from which resin it was first obtained as one of the products of destructive distillation. In combination with potash it also occurs in the milky juice of the leaves and stems of wormwood (*Artemisia absinthium*). It may be artificially prepared from stearic acid or other fatty matter by oxidation with nitric acid; in this reaction, pimelic and adipic acids are also formed, as well as a body that was at first thought to be a distinct acid (*lipic acid*), but which has since been shown to be identical with succinic acid. The most advantageous method of forming succinic acid is that known as Dessaigne's, and consists in fermenting crude malate of lime with eight or nine per cent. of decayed cheese and three times its weight of water. The mixture must be kept at a temperature of 100° Fahr. for about a week, when the malate will be found to be changed to a crystalline sediment of succinate and carbonate of lime, acetate of lime remaining in solution. The precipitate decomposed by boiling dilute sulphuric acid, and the solution evaporated and treated with animal charcoal furnishes the acid in rhombic prisms or tables.

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* The student may well ask *from where!* The term "carry" is not the proper one.

Succinic acid is inodorous and colourless, has an acid taste, and is very stable. It is very soluble in hot water, moderately so in cold water or alcohol, and only slightly soluble in ether. When heated it fuses at a temperature somewhere about 450° Fahr.; and above that point sublimes and condenses in a beautifully white crystalline mass of *succinic anhydride* ($C_8H_4O_6$); complete dehydration can, however, only be effected when the succinic acid has been previously mixed with phosphoric anhydride. Succinic acid is not acted on by nitric acid, chromic acid, chlorine, or even a mixture of hydrochloric acid and chlorate of potash. Heated with caustic potash it yields oxalate of the base and a carburetted hydrogen; and furnishes acetic acid by distillation with peroxide of manganese and acetic acid.

Succinates are, for the most part, either neutral salts ($2\,MO, C_8H_4O_6$) or acid salts ($MO, HO, C_8H_4O_6$). They are tolerably stable, and are characterised by giving a red-brown precipitate with persalts of iron.

Neutral succinate of potash contains ($2\,KO, C_8H_4O_6 + 4$ Aq.); *acid succinate of potash* ($KO, HO, C_8H_4O_6 + 4$ Aq.) The latter is the salt contained in wormwood; it crystallises in regular six-sided prisms, and is prepared by saturating a given quantity of succinic acid with carbonate of potash, and then adding a second quantity of the acid. *Succinate of ammonia* ($2\,NH_4O, C_8H_4O_6$) is sometimes employed to separate iron from nickel, cobalt, and manganese; the solutions must be perfectly neutral. *Succinate of soda* has been electrolysed by Kolbe; carbonic acid and oxide of methyl are evolved at the positive pole. Double *succinate of magnesia and potash* contains ($KO, MgO, C_8H_4O_6 +$ 5 Aq.).

Succinate of ethyl (succinic ether) ($2\,C_4H_5O, C_8H_4O_6$) is a liquid of specific gravity, 1·036; boiling point, 417·2° Fahr.; it is obtained on distilling succinic acid with alcohol and sulphuric acid; chlorine converts it into white acicular crystals of *perchlorosuccinate of perchlorethyl* (chlorosuccinic ether), ($2\,C_4Cl_5O, C_8Cl_4O_6$). The last-named body, by distillation, yields *chlorosuccide* ($C_6Cl_4O_2$); and by action of alkalies gives a salt containing *chlorosuccic acid* ($C_6HCl_3O_4$?).

Sulphosuccinic acid ($3\,HO, C_8H_3O_5, 2\,SO_3 + 2$ Aq.) is produced when anhydrous sulphuric acid and succinic acid are brought into contact. When pure it occurs in granular crystals, very soluble in water, alcohol, or ether; it is deliquescent, and requires three equivalents of base to saturate it.

Succinic oxychloride, or *chloride of succinyl* ($C_8H_4O_4Cl_2$), is a colourless highly refracting oil, obtained on distilling equivalent quantities of succinic anhydride and oxychloride of phosphorus. It fumes strongly, has a suffocating odour, boils at about 374° Fahr., and has a specific gravity of 1·39.

Succinyl ($C_8H_4O_4$)″ may be assumed to exist not only in the above compound, but also in all the other members of this group. If it exists it is diatomic, and plays the part of two equivalents of hydrogen.

Succinic amides are three in number. 1. *Succinamide* $\left(C_8H_8N_2O_4 = N_2\left\{\begin{array}{c} C_8H_4O_4'' \\ H_2 \\ H_2 \end{array}\right.\right)$. This substance is slowly formed, in colourless crystalline grains, on exposing a mixture of succinate of ethyl with twice its volume of strong solution of ammonia. It is insoluble in alcohol or ether, and almost insoluble in cold water; boiling water readily dissolves it, and the solution does not precipitate metallic salts. *Succinanilide*, or *diphenylsuccindiamide* $\left(C_{32}H_{16}N_2O_4 = N_2\left\{\begin{array}{c} C_8H_4O_4'' \\ (C_{12}H_5)_2 \\ H_2 \end{array}\right.\right)$ is the insoluble product of the action of succinic acid upon aniline. 2. *Succinamic acid* ($C_8H_7NO_6$) seems to have been obtained as a silver salt, but has not yet been isolated. *Succinanilic acid*, or *phenylsuccinamic acid*, contains $\left(C_{20}H_{11}NO_6 = N\left\{\begin{array}{c} C_8H_4O_4'' \\ C_{12}H_6 \end{array}\right., HO\right)$. 3. *Succinimide*, or *bisuccinimide* ($C_8H_5NO_4 + 2$ Aq.), is a product of the transformation of succinamide by heat. It crystallises in beautiful rhombic tables, is very soluble in water, less so in alcohol, and slightly so in ether. It melts at 410° Fahr. It is isomeric with succinamic acid, but does not combine with potash. *Chlorosuccinimide*, or *chlorozosuccic acid* ($C_8HCl_4NO_4$), results from the action of ammonia on chlorosuccinic ether. It may be easily separated from other bodies that are simultaneously formed, and then occurs in prisms; it is volatile, soluble in alcohol or ether, and decomposes carbonates with effervescence. *Succinanile* or *phenylsuccinimide* ($C_8H_4(C_{12}H_5)NO_4$), is that part of the product of the action of succinic acid upon aniline that is soluble in hot water. Purified by recrystallisation from alcohol, it forms beautiful colourless needles, insoluble in cold water, and volatile without decomposition.

SUCCINIMIDE. [SUCCINIC GROUP.]

SUCCINUM is a bituminous substance of a peculiar kind, the natural history of which has been already detailed. [AMBER, in NAT. HIST. DIV.] It is not now used in the crude state in medicine, but is employed to yield the oleum succini, or oil of amber. This is procured by the destructive distillation of amber, which is put into a glass, copper, or iron retort, fitted with a glass alembic properly luted. A gentle heat is applied by means of a sand-bath, by which the amber is melted, and a little volatile oil passes over; after this the amber swells greatly, and the distillation proceeds rapidly. By this process three very distinct products are obtained, namely, impure succinic acid, which adheres to the neck of the retort; an acid liquid (called spiritus volatilis succini), in which succinic and acetic acids exist mingled with empyreumatic oil; and, lastly, the volatile oil of amber, which is to be separated from the acid liquid by careful pouring off. What remains in the retort is *colophony* of amber, which is used to make varnish. The volatile oil thus obtained is impure, containing various pyrogenous ingredients, and requires repeated distillations to purify it. If in the third or fourth of these the process be interrupted when about two-thirds only of the oil has passed into the receiver, there is obtained a volatile oil of a light yellow colour, a peculiar bituminous odour, and of the specific gravity 0·880. If the distillation be continued too long, an empyreumatic oil is evolved, which gives to the other a coffee-brown hue; and this is the general appearance of rectified oil of amber. By some writers freshly prepared charcoal is directed to be put into the retort when the impure oil is to be distilled, but that is very improper, as by its means the pyrogenous principles, which it is the object of the rectification to separate, are very abundantly generated. The purest oil has a sharp burning taste, an acid re-action, and on exposure to the air becomes brown and inspissated. Various resinous matters substituted for amber may all be detected by the absence of succinic acid.

Volatile oil of amber probably contains a large portion of creasote, as may be inferred from the analogous action of nitric acid on it and on creasote. One part of rectified oil of amber, and three parts of moderately strong nitric acid, form a magma, which has the odour of musk, and is called *artificial musk*. Rectified oil of amber is stimulating, anti-spasmodic, and rubefacient. It is now little given internally, except in combination with ammonia, in the celebrated *eau-de-luce*, for which the *tinctura ammoniæ composita* of the Pharmacopœia was a substitute, but now omitted. This is to be applied to the nostrils in fainting, hysteria, and epilepsy, or a very few drops diluted with water may be taken internally. Oil of amber is beneficially rubbed along the spine in the later stages of hooping-cough. One ounce of rectified oil of amber, with half an ounce of tincture of opium, forms a good embrocation in tic-doloureux; its disagreeable odour is an obstacle to its employment when the face is the seat of the disease; but it proves a most valuable application when the limbs begin to lose their tone and swell in advanced life. It is extremely efficacious against the cramps of the limbs in Asiatic cholera, but which may be prevented by pressing the foot against a board or other firm body at the foot of the bed, when the patient feels cramp coming on.

SUCCINYL. [SUCCINIC GROUP.]

SUCCISTERENE. A white crystalline matter formed during the distillation of amber.

SUCROSE. [SUGAR.]

SUDORIC ACID ($C_{10}H_9NO_{14}$), *Hydrotic Acid.* In addition to lactic acid, there is contained in human perspiration the soda salt of another acid to which the above names have been given. Sudoric acid and its salts are uncrystallisable. The sudorate of silver has the formula $C_{10}H_8AgNO_{14}$. This salt is insoluble in alcohol; with this exception all the salts of sudoric acid are soluble in alcohol.

SUET is a variety of the fatty or adipose tissue of animals, accumulated in considerable quantity about the kidneys and the omentum, or caul, of several of the domestic quadrupeds. There are several kinds of it, according to the species of animal from which it is procured, such as that of the hart, the goat, the ox, and the sheep (ovis aries). This last, which is whiter than beef-suet is officinal. It belongs to the class of saponifiable fats. In the recent state it is white, easily broken, being solid at the ordinary temperature of the air, subdiaphanous, scarcely possessed of odour, or only of a slight peculiar one, due to the hircine, which in the process of saponification evolves a volatile strong-smelling acid (hircinic acid of Chevreul), but possessing a very disagreeable one when putrifying. It readily spoils on exposure to the air, becoming rancid and yellow, but may be restored again to whiteness by chloride of lime or chloride of magnesia. For this purpose, for each hundred parts of suet from two to four parts of chloride of lime are to be dissolved in from four to eight times its weight of water, and to be mixed warm, and as much dilute sulphuric acid is to be added as is necessary to decompose the chloride.

Suet consists of about three-fourths of stearine, with some elaine, and a little hircin and margarin; the preponderance of stearin renders it the most solid of animal fats, a circumstance which contributes to render it more indigestible than other fats. It liquefies with a gentle heat, and the prepared suet of the Pharmacopœia is obtained by melting it over a slow fire, and straining it, to separate the membranous portion. It is used as an ingredient in cerates, plasters, and ointments.

After being melted, it is little prone to spoiling, and by pouring it over various articles, such as potted char, minced collops, and mushrooms, from which it thoroughly excludes the air, it assists greatly in preserving them.

It has been employed also by M. Ludensdorff for preserving the *fleshy fungi*, or mushrooms, for botanical museums, by boiling them in it (which thus filled their pores and cells, and penetrated the very substance), and then covering them with a coat of varnish. It does not however always succeed in preserving the colour and form. (See Klotsch, in Hooker's 'Botanical Miscellany,' ii., p. 159.)

SUFFERANCE. [TENANT.]

SUFFICIENT REASON. (Mathematics and Physics.) The principle which is connected with these words might be, and frequently is, called the *want* of sufficient reason; and even this term may appear inaccurate, for it should be the want of *any possible amount* of reason. Since, however, all that takes place must have a sufficient reason (whether we know it or not) for its happening, and everything which is asserted must be capable, if true, of being shown to have a sufficient reason, there is no objection to our using the words "want of sufficient reason" in the sense of absolute want of reason, in all matters connected with the exact sciences. If A be equal to B, there must not only be reason, but reason enough for it: anything short of reason enough is no reason at all, and anything short of proof enough is no proof at all.

The use of the word reason in the statement of this principle may itself be fairly objected to. We are in the habit of speaking of mathematical consequences in the same manner as of those to which the notion of cause and effect applies. When one proposition is made to subserve the proof of another, we call the first, one of the reasons of the second, just as we should say that the reason of a flood was the preceding heavy rain. But this mode of speaking must be objectionable if the word reason be used in the same sense in both places. For, first, we are at liberty to deny the effect on denying that cause; if the rain had not fallen, the flood would not have taken place. But when we say that one mathematical proposition is the reason of another, in which position do we stand if we make an hypothetical denial of the first? Simply in that of persons who assert a contradiction of terms, and try to make rational consequences. Thus, the equality of the angles at the base of an isosceles triangle is one of the reasons (so called) why the tangent of a circle is at right angles to the radius; rationally, the first is one of the simpler propositions, the necessity of which, when seen, helps us to see the necessity of the second and more complicated one. But the necessity of the first is not previous to that of the second, except in the order of our perceptions, when we follow Euclid. Suppose we were to ask, if the angles at the base of the isosceles triangle had not been equal, what effect would that circumstance have had upon the position of the tangent of a circle? We might as well inquire what would our geometry have been if two straight lines had been capable of inclosing a space? We remember a book of arithmetic in which it was gravely asked, by way of exercise for the student, "If 6 had been the third part of 12, what would the quarter of 18 have been?" a question which can only be paralleled by "If a thing were both to exist and not to exist at one and the same moment, how many other non-existences would therefore become existences?"

Secondly, the term reason, in the sense of previous cause, is wrong as applied to mathematical propositions, because when any one is made to prove the second, it generally happens that the second, when granted, may be made to prove the first. Thus [RIGHT ANGLE] of the two propositions, "all right angles are equal," and "two lines which coincide between two points, coincide beyond them," one must be assumed, and the other will then follow: but either may be the one assumed; the other will follow. Now it is absurd to say that of two things each is the previous cause of the other. The whole of this confusion may be remedied by any one who will remember that one proposition is not the cause of another, but it is our *perception* of the one which is made the instrument of bringing about our *perception* of the other. The constitution of our faculties is the previous cause of the necessity of mathematical propositions, but not of one before another, though in arriving at the perception of this necessity our cognisance of the necessity of one is made the previous cause of that of the necessity of another. To say that B is the consequence of A, is only to say that our knowledge of the truth of B is the consequence of our knowledge of that of A.

Taking care to use the word reason in the sense just alluded to, we assume that whatever is necessary has a possibility of being shown to be necessary, and that whatever is true has a possibility of being shown to be true. If this be a legitimate assumption, it then follows that whatever it is impossible to show to be true, must be false. But can there be such a thing as a proposition of which there shall be seen, not its falsehood, but the impossibility of demonstrating its truth? Can there arise a case in which we shall be so completely cognisant of all that may possibly be said for or against an assertion, as to affirm a necessary incapability of demonstration of one side or the other? Such cases are universally admitted by mathematicians to exist; and the final assertion which is made on the known impossibility of proving a contradiction, is said to be made on the principle of the *want of sufficient reason*. But this very dangerous weapon is never put into the hands of a beginner, in mathematics at least. And when we call it a dangerous weapon, we do not deny its utility, but we only state what is well known to every mathematical teacher, that a student who is allowed to proceed one step by this principle will soon ask permission to make it the universal solvent of difficulties, and will be quite ready to urge that a proposition *cannot be shown to be false*, in preference to seeking for or following the demonstration that it *is true*. A beginner can easily admit a sound use of this principle, but can hardly distinguish it from the thousand inaccurate applications which his ignorance will make, if it be left in his own hands.

But we can imagine we hear it said that this principle, though sometimes employed in pure physics, is never introduced into mathematical reasoning except *after direct demonstration*, in order to confirm the mind of the learner by making him see how difficult it would have been to imagine the possibility of any contradiction being successfully maintained against the proposition *just proved*. We believe, indeed, that this principle is seldom employed, and always without necessity, so that we could wish its use were entirely abandoned. But we can show that a tacit appeal to it is sometimes made; and this is the worst possible mode of employing it. If the principle be dangerous, and liable to be unsoundly used, it should be most carefully stated when it is used. Whenever we see a proposition assumed, not as an express postulate, but in a definition for instance, or as a self-evident truth, we may trace the operation of this principle on our minds. For instance, take the proposition which is, if there be such a thing in any one proposition, a digest of all the methods of mathematics, namely, that if the same operations be performed on equal magnitudes, the resulting magnitudes are equal. Try to imagine this not true, and want of sufficient reason interferes to prevent success. *What can make a difference?* In this question the principle claims to be applied.

Now, first, in examining the definitions of Euclid, we find an assertion of theorems which we can hardly suppose that Euclid overlooked, though it is very possible that the impossibility of imagining otherwise may have been his guide. For instance, the assertion of the equality of the two parts into which a diameter divides a circle, following immediately upon the definition of a circle; and the definition of equal solids as those which are contained by the same number of plane figures equal each to each. These and such little matters have been, or may be, corrected; but we will now point out a use of the principle which exists in our elementary works of the present day in an unacknowledged form.

In proving the celebrated proposition of Albert Girard relative to the dependence of the area of a spherical triangle upon the sum of its angles, it is assumed that two spherical triangles which have their sides and angles equal, each to each, are equal in area. Now it is easily shown [SYMMETRY] that there may be two such triangles of which it is impossible to make one coincide with the other, nor is any process ever given for dividing each into parts, so that the parts of one may be capable of coinciding with those of the other. Let the angular points of one be placed upon the angular points of the other (which is always possible), and the triangles will not coincide; in common language, they will *bulge* in different directions. When the triangles are so placed, and the common chords drawn, there is no difficulty in seeing that if ever a want of sufficient reason can be granted upon perception, it is for there being any inequality of the areas of the two triangles. And the equality of these areas is accordingly assumed: for instance, in the proposition above alluded to, a pair of unsymmetrically equal triangles always occurs, except when the given triangle is isosceles. And thus the appeal to this principle may be avoided; for it is easy to make the given triangles into the sum or difference of isosceles triangles, in which each of one set is capable of being actually applied to one of the other.

Leaving the subject of pure mathematics, let us now consider the application of this principle in physics. We have observed [STATICS] that the line of separation between pure mathematics and the more exact parts of mathematical physics is very slight indeed: this means as to the clearness and fewness of the first principles, and the rigour of the demonstrations. If we cut the link which ties the sciences of statics and dynamics to the properties of the matter which actually exists around us, we may go farther, and say that we have not only pure sciences, but pure sciences in which the principle of the want of sufficient reason is strictly applicable, because it is our own selves who have, by express hypothesis, excluded sufficient reason. In propositions of pure mathematics, we have seen that we cannot invent or deny for any hypothetical purpose; *is* and *must be*, *is not* and *cannot be*, are synonymes, in all the truths which these sciences teach. But the properties of matter which are not also those of space, are not, in our conceptions, necessary: we can imagine them other than they are, without any contradiction of ideas.

We shall now proceed to consider the point mentioned in STATICS, namely, the character of the axioms of that science. Are they "self-evidently true," and "not to be learnt from without, but from within?" We will not here inquire whether the first must be the second, not being sufficiently clear as to what is meant by knowledge "from without" and knowledge "from within," to enter upon any such investigation. It will do for our purpose to take knowledge "from within" to be a phrase descriptive of such truths as that two straight lines cannot inclose a space, and knowledge "from without" another phrase indicating such truths as are found, say in the facts of political history or geography. Let us separate from the rest one axiom of statics, say "equal weights at the ends of equal arms of a horizontal straight lever balance one another." First, "equal weights" is a synonyme for equal and parallel pressures. We have no objection to placing the idea of pressure on the same footing as that of a straight line, for be the name we give the former conception what it may, it is probable that those powers of communication with the external world which are certainly necessary to the development, at least, of pressure, are not less necessary to that of straightness. Nor are equal pressures difficult of definition; let them be those which are interchangeable, so that either may be put in the place of the other. The rest of the terms of the axiom are geometrical, and to balance each other is to produce no motion,—motion, independently of producing causes, being, we think, as much an idea of geometry as any other. Let A and B be the two ends of a lever (a rigid bar without weight), and C its middle point, which is the pivot; that is to say, the middle point cannot move, the only possible motion of the lever being revolution, in the plane of the pressures, about that middle point. On these hypotheses, we may certainly say that the axiom is self-evident, for want of sufficient reason, that is, of a possibility of sufficient reason for anything in contradiction of it. We have, before the pressures are applied, no cause of motion, by hypothesis: we are to conceive a lever, which, if it move at all, does so by reason of the pressures. We have made these pressures equal, and applied them symmetrically: there is then, and can be, no reason why one should predominate, which does not hold as much of the other. In the very notion of equality of pressures there is interchangeability; that is, each may be substituted for the other without alteration of effect. Suppose then the left-hand pressure to predominate: it will do so if the pressures be interchanged. But after the interchange the same reasons which made the left hand predominate, will make the right hand predominate: or both ends will move in the direction of the pressures, which is impossible.

We believe the preceding to be as legitimate a use as can be made of the sufficient-reason principle; but before statics can be established on axioms, there is another of them required, which we have never been able to satisfy ourselves comes "from within." It must be assumed that the pressure on the pivot is equal to the sum of the pressures on the ends, whatever the length of the arms may be: this we believe *we learn* from existing matter in quite a different sense from that in which we speak when we say that we learn the conception of pressure or of a straight line from our communication with the external world by our senses: to us it more resembles the assertion that the sea is salt, or that a horse has four legs. It certainly does not arise from the sufficient-reason principle; for there is a reason why difference of pressures on the pivots may arise in levers which only differ in the arms, namely, that very difference of the arms. In fact, there is a presumption against the truth of the proposition *à priori*, derived from a principle the frequent and usual truth of which may as well be called knowledge "from within," as the conception of pressure or of a straight line: this principle is, "differences generally make differences, but not necessarily." The beginner in geometry has this in his mind when he feels that he has learnt something in finding out that the sum of the angles of a triangle is always the same, whatever the triangle may be: he would have expected it to be otherwise. Triangles of different sides have generally different areas, different perpendiculars, different inscribed and circumscribed circles, and different angles: why not different sums of angles? In truth it is a constant and latent assumption throughout the exact sciences that "differences are to be supposed to make differences, except where the contrary is proved." And the assumption that the pressure on the pivot of a lever is independent of the arms, is either in defiance of this general principle, or a result of experience.

Thinking, then, that the sciences of pure mechanics can be founded upon few and incontrovertible postulates, in such a manner as to entitle them to the name of pure sciences, or some other which shall mark the real distinction between them and the other sciences of matter, we cannot yet be of opinion that their postulates are all derived from their own evidence, or obtainable from the sufficient-reason principle. There are, however, many points connected with this part of them which are difficult of exposition for want of acknowledged terms.

SUFFIX, a term lately employed in mathematical language to denote the indices which are written under letters, as in a_0 a_1 a_2 a_3, &c. Though these signs have been so long used, we never saw a distinctive name given to them before the publication of Professor Hall's 'Differential Calculus.'

SUFFRAGAN. [BISHOP.]

SUGAR. Referring to SUGAR in the NATURAL HISTORY DIVISION of this Cyclopædia for an account of its distribution in the organic kingdom, and to a separate article [SUGAR CULTURE AND MANUFACTURE] for information concerning the extraction from the sugar-cane, and purification of common or cane-sugar, we shall at present only consider sugar from a chemical point of view.

Sugar—in Persian, *shukkur*, and originally *sarkara* (Sanscrit)—may be defined as a body having a sweet taste, and which, under the influence, direct or indirect, of ferments, splits up into alcohol and carbonic acid. As few plants are wholly destitute of sugar, and as many contain it in considerable proportions, it is not surprising that many so-called varieties of sugar should have been described from time to time. Thus we read of sugar of starch, sugar of raisins, sugar of milk, sugar of gelatine, cane-sugar, grape-sugar, manna-sugar, &c. &c. Many of these, however, have been shown to be identical, and at present nearly all may be included under four varieties, namely: *Sucrose*, or cane-sugar, including sugar from the beet-root, turnip, carrot, maple, birch, palm, Indian corn, and many fruits of tropical plants; *Glucose*, including grape-sugar, starch-sugar, and the sugar generally found in dried fruits; *Fructose*, the state in which sugar exists in recently plucked fruits; and *Lactose*, the sweet principle found in the milk of animals.

Berthelot divides the whole class of sugars, properly so called, into two fundamental groups, of which sucrose and glucose are the respective types. The glucose group is characterised by fermenting directly in contact with yeast; by being destroyed by strong alkalies, even in the cold, and readily at 212° Fahr.; by the reducing action on potassio-tartrate of copper; and by the circumstance that when dried in a water-bath the members of this group are isomeric, having the formula $C_{12}H_{12}O_{12}$. The members of the glucose group differ from each other in their crystalline form; in their rotatory power on polarised light [SACCHARIMETRY]; in the modifications they undergo when exposed to the influence of heat or acids; in the nature of their combinations with water, bases, and chloride of sodium; and in the manner of their conversion into mucic acid, &c. Under the sucrose group, Berthelot includes all sweet principles analogous to cane-sugar; they with difficulty ferment under the influence of yeast; are scarcely changed by alkalies, or by potassio-tartrate of copper, even at a temperature of 212° Fahr.; are, by the action of acids, readily converted into new sugars belonging to the glucose group; and are isomeric only when heated to 266° Fahr., having then the composition $C_{12}H_{11}O_{11}$. The members of the sucrose group are distinguished from each other by their crystalline form; rotatory power; unequal resistance to heat, acids, and ferments; in their behaviour to bodies with which they combine; and in the formation of mucic acid, &c. Sugar of milk (lactose), however, stands in a position intermediate between the above groups; resembling the glucose series in the action of alkalies and copper-salts upon it, it is nevertheless analogous to sucrose in resisting the action of heat and ferments, and capability of being converted into a fermentible sugar.

The four chief varieties of sugar differ slightly from each other in composition, and very widely in appearance and sweetening power. Sucrose has the formula $C_{12}H_{11}O_{11}$, or possibly double that ($C_{24}H_{22}O_{22}$); its appearance and taste are well known. Glucose, or grape-sugar ($C_{12}H_{12}O_{12}+2Aq.$) has considerably less than half the sweetening power of cane-sugar, and is generally met with as a somewhat soft and granular, rather than crystalline mass. Fructose (*chularicose*) ($C_{12}H_{12}O_{12}$) is also less sweet than sucrose, and is, moreover, uncrystallisable. And finally, lactose ($C_{24}H_{24}O_{24}$) occurs in hard, gritty, mammillated crystalline masses, and is considerably inferior in sweetness to any of the other sugars.

Cane Sugar ($C_{12}H_{11}O_{11}$)—is colourless, inodorous, of a purely sweet taste, moderately hard, and brittle. The crystals, when rapidly formed, as in common refined sugar, are small; but when obtained by the slow evaporation of a strong solution, they are of considerable size (sugar candy). The specific gravity of sugar is about 1·6: it undergoes no change by exposure to the air; and, when moderately heated, loses only a little hygrometric moisture: it is soluble in one-third of its weight of cold water, and in all proportions in hot water: a solution saturated at 230° forms, on cooling, a mass of small crystals. It is soluble in alcohol, but much less so than in water; absolute alcohol takes up only 1-80th of its weight, even when boiling, and this separates in small crystals as the solution cools: spirit of wine, of specific gravity 0·830, dissolves nearly one-fourth of its weight. Sugar is phosphorescent when two pieces are rubbed together in the dark. Heated to about 320° Fahr., sugar melts into a viscid colourless liquid, which, cooled suddenly, becomes a transparent mass (barley-sugar); by keeping, it becomes opaque. At 400° to 420° sugar is converted into CARAMEL, or *burnt sugar* ($C_{12}H_9O_9$), two equivalents of water being set free. When exposed to a higher temperature, sugar undergoes decomposition, yielding various gaseous products, and leaving a large proportion of charcoal. Acids produce very different effects upon sugar: thus nitric acid decomposes and is decomposed by it, the principal products being nitric oxide, carbonic, oxalic, and saccharic acids: sulphuric acid, when concentrated, attacks sugar itself, or even a strong solution of it, sulphurous and carbonic acid gases being formed and evolved, and a large quantity of carbon set free; 1-100th of a grain of sugar, on account of the large proportion of carbon which it contains, is capable of imparting colour to an ounce of sulphuric acid. When sugar, dissolved in dilute sulphuric acid, is kept for a long time at a high temperature, it absorbs oxygen from the air, formic acid is produced, and there is deposited a brown insoluble matter termed *ulmin*. Ulmin is sometimes formed when recently expressed cane juice is heated, a small portion of lime, however, neutralises the acid in the juice, and prevents its formation. Hydrochloric acid dissolves sugar, and forms with it a thick black resinous paste. A simple solution of sugar in water undergoes change slowly when exposed to the air, but on the addition of yeast it undergoes rapid fermentation, and is converted, first into grape-sugar, and then into alcohol.

Sugar in many cases combines with the alkalies, earths, and metallic oxides, and, in some cases, forms definite compounds with them called *saccharates*, or *saccharides*. With ammonia, according to Berzelius, sugar combines to form a compound of one equivalent of each; but by exposure to the air the ammonia escapes, and leaves the sugar unaltered: potash and soda appear also to combine with sugar, and they destroy its sweetness; this is restored when the alkalies are saturated with an acid: but if they be left long in contact, the sugar becomes changed into a substance resembling gum.

Lime, baryta, and oxide of lead dissolve in considerable quantity in a solution of sugar: when the first-mentioned of these bodies, in the state of hydrate, is digested at a moderate heat in a solution of sugar, a bitter alkaline solution is obtained, in which the sugar is combined with an equivalent of lime ($CaO, C_{12}H_{11}O_{11}$). Professor Daniell obtained, by the action of these bodies, gum and crystals of carbonate of lime.

The compound of sugar and baryta is similar. When hydrated oxide of lead is digested in a solution of sugar, a yellow alkaline liquid is formed, which yields a tough deliquescent mass by evaporation; but when excess of the oxide is boiled in a solution of sugar, and the liquor is filtered hot, it deposits eventually a tasteless insoluble compound, containing 2 $PbO, C_{12}H_{10}O_{10}$.

Sugar dissolves carbonate and diacetate of copper, forming green solutions which are not decomposed by the alkalies, and this is also the case with the salts of iron. A crystalline compound of sugar and common salt may be formed by the spontaneous evaporation of a solution of four parts of the former and one part of the latter. According to Peligot it contains $NaCe, HO, C_{12}H_9O_9 + C_{12}H_{11}O_{11}$.

Distilled with eight times its weight of quicklime, sugar furnishes Metacetone. Chlorine transforms sugar into a brown substance partially soluble in water.

For the action of solutions of sugar on a ray of polarised light, and estimation of the strength of a solution of sugar, see Saccharimetry.

The uses of cane sugar are too well known to require much notice: on account of its antiseptic power, it is employed to preserve various vegetable products: it is used as a sweetener of many kinds of food, and is in these cases nutritious; but being destitute of nitrogen it is, like other substances similarly constituted, incapable of supporting life for any length of time.

Maple Sugar, when refined, is equal in appearance and sweetening power to refined cane-sugar; and in composition they are similar.

Beet-root Sugar is exactly similar to cane-sugar.

Grape-sugar, or *glucose* ($C_{12}H_{12}O_{12}$, 2Aq.), or *starch-sugar*. Besides the sources previously mentioned, this variety of sugar has been lately shown to be a constituent of healthy urine. Under the name of diabetic sugar it occurs in abnormal quantities in the urine of patients afflicted with diabetes; under these circumstances it is readily detected on adding to a small quantity of the urine contained in a test-tube, first, solution of potash or soda, next a few drops of solution of sulphate of copper, and then gradually heating to the boiling point, when an abundant deposit of red suboxide of copper will be formed if sugar be present in abnormal quantity. The same test may, of course, be applied to any other solution suspected to contain glucose.

Grape-sugar is produced in quantity by allowing a cream of starch and water to flow into water containing one per cent. of sulphuric acid, at a temperature of 130° Fahr. The whole is ultimately boiled for a short time, the sulphuric acid neutralised by chalk, and the solution evaporated down and set aside to crystallise.

Glucose forms combinations with bases which are rapidly decomposed, yielding Glucic Acid. When heated, they yield uncrystallisable Melassic Acid. Combinations of glucic acid with certain crystalline principles occur naturally; several are described under Glucosides.

Heated to about 140° Fahr., grape-sugar softens, and at 212° Fahr. melts, and loses two equivalents of water. At a higher temperature it is converted into caramel. Water dissolves less of grape than of cane-sugar, the solution is less viscid, and it is not so sweet; hot alcohol, however, dissolves more of it, but it is deposited again on cooling in crystalline grains. With sulphuric acid, instead of being charred, as cane-sugar is, it forms a compound acid called *sulphosaccharic acid*, *sulphoglucic*, *sulpholignic*, *vegeto-sulphuric*, or *sulphamidonic acid*, which gives no precipitate with the salts of barium.

Honey contains both fructose, or uncrystallisable sugar, and glucose-sugar. The two may be separated by strong alcohol, which dissolves the fructose and leaves the grape-sugar behind.

Manna Sugar. [Mannite.]

Mushroom Sugar. [Mannite.]

Liquorice Sugar, so-called, is not a true sugar. See Glycyrrhizin.

Sugar of Milk, *Lactine*, or *Lactose* ($C_{24}H_{24}O_{24}$), is obtained by evaporating the whey of milk to its crystallising point; it forms colourless four-sided prisms, which are soluble in about six parts of cold water and two and a half parts of hot: the taste of this sugar is not very sweet, it is unalterable in the air, and is insoluble in alcohol and ether. Boiled with dilute acids, it is slowly converted into glucose. It forms two insoluble compounds with oxide of lead; and reduces boiling solutions of salts of copper, mercury, or silver.

Melitose, *trehalose*, and *melezitose*, are three varieties of sugar lately discovered by M. Berthelot. They are closely allied to cane-sugar. Melitose is contained in Australian manna, a product of the *Eucalyptus*; by fermentation it yields a non-crystalline body, termed *Eucalyn* ($C_{12}H_{12}O_{12}$, 2HO). *Trehalose*, is contained in Turkish manna, a substance formed by an insect (*Larimus nidificans*) at the expense of a plant of the genus *Echinops*; it seems to be identical with the *mycose* of Mitscherlich, a sweet principle contained in ergot of rye. *Melezitose* occurs in Briançon manna, an exudation from the larch tree.

Sorbin ($C_{12}H_{12}O_{12}$) is a sugar contained in the berries of the mountain ash (*Sorbus ancuparia*). Heat transforms it into a deep red matter, termed *sorbinic acid*.

SUGAR CULTURE AND MANUFACTURE. Sugar is a sweet crystallised substance, most commonly prepared from the expressed juice of the sugar-cane, of which there are several species; but sometimes from beet-root, from the sap of one or more species of maple, and from other vegetable productions. Saccharine matter is indeed one of the most common of vegetable secretions, but it is only from the above-mentioned substances that sugar has been extracted to any great extent as an article of commerce; and of these the sugar-cane is by far the most extensively used. The sensation of sweetness is indeed produced not only by many vegetable and animal substances, but also by some of purely chemical character. The muscular parts of all quadrupeds, birds, and fishes, if boiled or roasted soon after death, have a decided though slight degree of sweetness; which sweetness disappears on the commencement of the spontaneous change which ends in putrefactive decomposition. Glycerin is a sweet substance obtainable from most of the fats or expressed oils, whether animal or vegetable, by the process of saponification. The sweet taste of new milk is occasioned by a saccharine substance called sugar of milk. Honey-dew, or aphis-sugar, and the honey of the bee, are intermediate between animal and vegetable sugars; because, though derived from vegetable juices, they are modified by digestion in the stomachs of insects. Among vegetables which contain sugar ready formed (though not in a crystallised or separate state), there are several trees from the sap of which it may be obtained in sufficient quantity for human use. Two of these—the sycamore and the birch—are natives of Britain; but the sugar which they yield is not sufficient to repay the expense of manufacture. The sugar-maple, which abounds in some parts of North America, yields sugar in such abundance as to be of considerable importance. Many trees of the palm family afford a sweet sap, which may be boiled down to a tolerably solid viscid sugar. Saccharine matter exists in many ripe fruits in great abundance, as is evident not only from their sweet taste, but also from the circumstance that it exudes from some, such as the fig and the grape, in the process of drying. Several roots, particularly of the tuberous or fleshy kind, contain sufficient saccharine matter to be commercially important, either for separating it in a pure state, or in the form of an extract of all the soluble ingredients of the root. Of the latter class liquorice is one of the most important. For the former purpose, attempts have been made upon several fleshy roots employed as food. Marggraf (in 1747) tried the skirret (a variety of parsnep), the white beet, and the red beet. His experiments were resumed some years afterwards by M. Achard, at the desire of the Prussian government. Probably these and some other early experiments led, in some degree, to the subsequent introduction of the manufacture of beet-root sugar in France under M. Chaptal.

The above details show how many sources there are from which sugar might be obtained. None of them, however, as far as experiment has shown hitherto, will bear comparison with the sugar-cane in point of cheapness; beet-root sugar indeed has entered into competition with that from the cane, but only successfully when aided by fiscal regulations.

History of Cane Sugar.—Unless we suppose the sacred writers to have alluded to it, Herodotus is probably the earliest author who mentioned sugar. Theophrastus describes three kinds of honey—from flowers, from the air (apparently honey-dew), and from canes or reeds; and in another place he describes a reed or cane that grew in moist places in Egypt, which was sweet even to the roots. From some passages in early writers it would seem that the juice of the cane was used as a drink. The term "honey of canes," which appears to indicate a fluid or semi-fluid consistency, was used by Avicenna, as late as the tenth century. Dioscorides, about the period of the reign of Nero, is said to be the first writer who uses the word *Saccharum* (σακχαρον), or sugar; but though he gives an accurate description of it, he was evidently unacquainted with the process by which it was prepared. He says "it is in consistency like salt, and it is brittle between the teeth like salt." Seneca speaks of sugar as honey found on the leaves of canes, which is produced by the dew, or the sweet juice of the cane itself, concreting; thereby showing the like ignorance of its real character. Pliny speaks of sugar as brought from Arabia, and better from India. "It is," he says, "honey collected from canes, like a gum, white, and brittle between the teeth; the largest is of the size of a hazel-nut. It is used in medicine only." Galen, in the second century, gives a description of sugar almost identical with that of Dioscorides, excepting that he says nothing of its brittleness and resemblance to salt. These qualities are however again mentioned by Paulus Ægineta, in the 7th century, who, following Archigenes, an earlier writer, describes sugar as "the Indian salt, in colour and form like common salt, but in taste and sweetness like honey."

Such notices might be extended much further; but enough has been stated to show that sugar was known, and was an article of commerce, at least as early as the commencement of the Christian era; and also to prove that its origin was very imperfectly understood by ancient Greek and Roman writers. Although more than one writer speaks of sugar as coming from Arabia as well as India, it was probably not made in the former country. Indeed the early Arabian writers themselves speak of sugar as coming from India. It appears probable that the white sugar-candy of China, which has been very long celebrated for its excellence, was the Indian salt of the Roman authors. The historians of the crusades describe the sugar-cane as met with by the Crusaders in Syria. One of these, Albertus Agnensis, about the year 1108, says that "sweet honied reeds," which were called *Zucra*, were found in great quantity in the meadows about Tripoli. These reeds were sucked by the crusaders' army, who were much pleased with their sweet taste; and our author gives the oldest description extant of the process of extracting sugar from the cane. Another of these historians, Jacobus de Vitriaco, in 1124, says that in Syria reeds grow that are full of honey; by which he understands a sweet juice which, by the pressure of a screw-engine, and concreted by fire, becomes sugar. About the same time William of Tyre speaks of sugar as made in the neighbourhood of Tyre, and sent from thence to the farthest parts of the world. As early as the time of the emperor Frederick Barbarossa, sugar was produced in great quantity in Sicily, and used in two states; either boiled down to the consistence of honey, or boiled further, so as to form a solid body of sugar. About 1306, sugar was made in the countries subject to the Sultan, and also in Cyprus, Rhodes, Amorea, Sicily, and other places belonging to the Christians. The progress made in introducing the sugar-cane, and the process of extracting sugar from it, into the islands of the Mediterranean, into Italy, and into Spain, were derived from the Arabs, and were in some degree connected with the increased communication with the East occasioned by the Crusades. It is stated by Venetian historians that in the 12th century Venice could import sugar cheaper from Sicily than from Egypt. The manufacture of sugar was probably introduced into Spain by the Moors. About 1420 the Portuguese took the sugar-cane from Sicily to Madeira; and probably during the 15th century, it was carried from Spain to the Canaries. From these sources, the cultivation of the sugar-cane, and the art of making sugar, were extended by different nations of Europe to the West Indian islands and the Brazils. Wherever the sugar-cane may have been indigenous, there is no reason to question the fact that the manufacture of sugar, derived originally from China and India, was introduced into the western world by the Spanish and Portuguese. In Hispaniola, or St. Domingo, there were, as early as 1518, twenty-eight sugar-works, established by the Spaniards. Peter Martyr, who gives this information, remarks on the extraordinary growth of the cane in that island; which, for a long period, afforded the principal supply of sugar to Europe. Antwerp, about 1560, received sugar from Spain,—which had it from the Canaries; and also from Portugal, the latter country deriving it from S. Thomé and other islands on the African coast, and from Madeira. Sugar was also an article of import from Barbary.

Whatever may have been the precise period of the commencement of the English sugar-manufacture in Barbadoes, Anderson states that in 1627, and for several years later, the Portuguese supplied most parts of Europe with Brazil sugars. About 1650 the British planters in Barbadoes appear to have been realising property very rapidly by the raising of sugar; they having obtained a few years before, valuable information from Brazil respecting the culture and process of extracting sugar from the cane. In 1676 the sugar trade of Barbadoes is said to have attained its maximum, being then capable of employing 400 vessels, averaging 150 tons burden.

Cultivation of the Sugar-Cane.—The botanical characters of the sugar-cane are given under SACCHARUM, in NAT. HIST. DIV., where also the principal species are mentioned. The height attained by the canes, their colour, the length of their joints, and many other particulars, vary with different species, with the character of the soil, and with the modes of culture adopted. The stems vary in height from eight feet up to twenty feet, and are divided by prominent annular joints into short lengths. Long narrow leaves sprout from each joint; but as the canes approach maturity, all the leaves from the lower joints fall off. The outer part of the cane is hard and brittle, but the inner consists of a soft pith, which contains the sweet juice; this juice is elaborated separately in each joint, independently of those above and below it. The canes are usually propagated by slips or cuttings, consisting of the top of the cane, with two or three of the upper joints, the leaves being stripped off. These are planted either in holes dug by hand, or in trenches formed by a plough, from eight to twelve inches deep. Three feet between the rows, and two feet between the holes in the rows, are about the minimum distances; but when the horse-hoe is used to keep the ground clear from weeds, the distances are usually increased to five feet and two and a half feet respectively. Two or more slips are laid longitudinally at the bottom of each hole, and covered with earth from the banks, to the depth of one or two inches. In about a fortnight the sprouts appear a little above the earth, and then a little more earth from the bank is put into the hole; and as the plants continue to grow the earth is occasionally filled in, by a little at a time, until, after four or five months, the holes are entirely filled up. From August to November is generally considered the best time for planting in the British West Indies; and about March and April is perhaps the most generally approved time for cutting the canes, although that operation is sometimes performed through a great part of the year. The maturity of the cane is indicated by the skin becoming dry, smooth, and brittle; by the cane becoming heavy; the pith gray, approaching to brown; and the juice sweet and glutinous. The canes which grow immediately from the planted slips are called *plant-canes;* but it is usual, in the West Indies, to raise several crops in successive years from the same roots; the canes which sprout up from the old roots, or *stoles*, being called *rattoons*. The rattoons are not so vigorous as the original plant-canes; but they afford better sugar, and that with less trouble in clarifying and concentrating the juice. Some planters have, under favourable circumstances, raised rattoon crops for more than twenty years successively, from the same stoles. The canes should be cut as near the ground as possible, because the richest juice is found in the lower joints. One or two of the top joints of the cane are cut off, and the remainder is divided into pieces about a yard long, tied up in bundles, and carried immediately to the mill. The upper branches of the cane are used as food for cattle; the remainder of the waste forms a valuable manure, for which purpose the *trash* or waste from the mill is admirably suited, though much of it is usually consumed as fuel.

Preparation of Raw Sugar.—The operation of cutting the canes is so adjusted as to keep pace with the action of the mill by which the juice is to be pressed out; so that the canes may be crushed or ground while quite fresh. In the East Indies mills of very rude and imperfect construction are used; some of them resembling mortars, formed of the lower part of the trunks of trees, in which the canes are crushed by the rolling motion of a pestle, moved by oxen yoked to a horizontal bar. The expressed juice runs off by a hole bored obliquely from the lower part of the mortar-like cavity, and is conducted by a spout to a vessel placed to receive it. In order to make such a mill effective, it is necessary to cut the cane into very small pieces. Other mills are capable of being moved from place to place, so that they may accompany the movements of the cane-cutters. One of these consists of two vertical rollers of hard wood, having, near their upper ends, endless screws, or spiral ridges, so fitting into each other that both rollers may revolve when rotatory motion is applied to either. The axis of one of the rollers is prolonged vertically above the framing, and carries a beam to which oxen are yoked to turn the mill. This appears to be the prototype of the vertical mill long used in the West India colonies. Another, still simpler, consisting of two grooved rollers placed horizontally in contact with each other, and turned by the power of men applied to levers at their ends, appears, in like manner, to be the rude original of the improved horizontal mills introduced of late years. The common vertical cane-mills of the West Indies consist of three rollers, usually of wood, with narrow strips of iron attached to their faces, so as to form, by the spaces left between them, straight grooves extending from end to end of the rollers. The moving-power is applied to the middle roller, and communicated from it to the others by cogged wheels. Of late steam-engines have been adopted with good effect in some of the sugar-works in the West Indies. In using the mill, a negro applies the canes in a regular layer or sheet to the interval between the first and second rollers, which seize and compress the canes violently as they pass between them. The ends of the canes are then turned, either by another negro on the opposite side to the feeder, or by a framework of wood called a *dumb returner*, so that they may pass back again between the second and third rollers. As these are placed nearer together than the first and second, they compress the canes still more, so that on leaving them they are reduced to the form of dry splinters, which are called *cane-trash*. Channels are added to receive the liquor expressed from the canes, and to conduct it to the vessels in which it is to undergo the succeeding operations.

The construction of this mill is very defective. A better form is that of placing the rollers in a horizontal position, and feeding the mill by sliding the canes gradually from an inclined board. The rollers, made very accurately of cast-iron, and fluted or grooved on the surface, are not placed in the same plane, but are arranged in a triangular form, the periphery of the upper roller being very nearly in contact with the two lower rollers, which are also very near together. The two lower rollers, which are called respectively the feeding and delivering rollers, have small flanges at their ends, between which the top roller is placed, so that the pressed canes may not be able to escape from the rollers and clog the machinery. The feed-board is an inclined plane, commonly of cast-iron, the edge of which is nearly in contact with the feeding roller. The delivering board, which receives and conducts away the *trash* of the cane, is also of cast-iron, sloping downwards from the delivering roller. In some cases the liquor is raised from the gutter of the mill-bed by pumps connected with and worked by the machinery of the mill. Where circumstances render such an arrangement practicable, labour may be saved by placing the crushing-mill on a high level, so that the liquor may run from it to the vessels in which it is to be purified, by inclined gutters. In Demerara a well-constructed engine and mill will produce about a hundred gallons of liquor per hour for each horse-power.

Cane-juice, as expressed by the mill, is an opaque, slightly viscid fluid, of a dull gray, olive, or olive-green colour, of a sweet balmy taste, and of a specific gravity varying from 1·033 to 1·106. It holds in suspension particles of solid matter from the cane, a considerable portion of which is separable by filtration or repose. The juice is so exceedingly fermentable, that in the climate of the West Indies it would often run into the acetous fermentation in twenty minutes after leaving the mill, if the process of clarifying were not immediately commenced.

We have next to treat of the extraction of the sugar from the juice. As practised in the East Indies, the liquor, after being strained so as to separate the coarser feculencies, is boiled down in open boilers into a thick inspissated juice; the scum which rises during the operation being removed. When it is sufficiently evaporated, it is removed into earthen pots to cool, and in these it becomes a dark-coloured, soft, viscid mass, called *goor*, or *jaggery*. Much of the molasses or uncrystallisable part of the juice is then separated, by putting the goor into a coarse cloth and subjecting it to pressure. The sugar is further purified by boiling it with water, with the addition of an alkaline solution and a quantity of milk. When this has been continued until scum no longer rises upon the liquor, it is evaporated, and sometimes strained, and afterwards transferred to earthen pots or jars. After it has been left for a few days to granulate, holes in the pots are unstopped, and the molasses drains off into vessels placed to receive it. The sugar is rendered still purer and whiter by covering it with the moist leaves of some succulent aquatic plant, the moisture from which drains slowly through the sugar, and carries with it the dark-coloured molasses. A similar process to the above is said to be practised in Cochin China.

The separation of the sugar from the cane-juice is effected in a much simpler manner in the West Indies. The juice is conducted by gutters from the mill to large flat-bottomed pans, called *clarifiers*. Each of these is placed over a fire, which may be regulated or extinguished by a damper; and each is supplied with a stop-cock or siphon for drawing off the liquor. When the clarifier is filled with juice, a little slaked lime is added to it; the lime, which is called *temper*, being, in most cases, previously mixed with a little cane-juice to the consistence of cream. As the liquor in the clarifier becomes hot, the solid portions of the cane-juice coagulate, and are thrown up in the form of scum. The proper heat is indicated by the scum rising in blisters and breaking into white froth, which commonly happens about forty minutes after the fire is lighted. The damper is then closed, and the fire dies out; and after an hour's repose, the liquor is ready for removal to the first of the evaporating pans.

From the clarifier the purified juice, bright, clear, and of a yellow wine colour, is transferred to the largest of a series of evaporating pans, three or more in number. These evaporators are placed over a long flue, heated by a fire at one end, over which the smallest of the coppers, called the *teache*, is placed. In the process of boiling, impurities are thrown up in the form of scum, which is carefully removed. In the *teache*, the liquor is boiled down to as thick a consistency as is considered necessary for granulation; this point being most commonly ascertained by observing to what length a thread of the viscid syrup may be drawn between the thumb and finger. This trial by the *touch*, whence the teache is supposed to derive its name, is very imperfect; for it sometimes happens that the syrup may have the required tenacity, and yet not be in a good state for crystallising. The latter point may be better ascertained by observing the incipient granulation of the syrup on the back of a ladle dipped in the teache. The thermometer, though useful, will not be a sure guide in determining the proper moment for *striking*, or emptying the teache; because a viscous syrup, containing much gluten and sugar, altered by lime, requires a higher temperature to enable it to granulate than a pure saccharine syrup. The concentrated syrup is ladled, or *skipped*, from the teache, either immediately into open wooden boxes called *coolers*, or into a large cylindrical cooler, from which it is afterwards transferred to the granulating vessels. In these the sugar is brought to the state of a soft mass of crystals, imbedded in thick, viscid, but uncrystallisable fluid. The separation of this fluid is the next process, and is performed in the *curing-house*. This is a large building, the floor of which is excavated to form the molasses reservoir. Over this cistern is an open framing of joists, upon which stand a number of empty *potting-casks*; each of these has eight or ten holes bored through the lower end, and in each hole is placed the stalk of a plantain-leaf. The soft concrete sugar is removed from the coolers into these casks, in which the molasses gradually drains from the crystalline portion, percolating through the spongy plantain-stalks.

When it leaves the curing-house the sugar is packed in hogsheads for shipment as *raw*, *brown*, or *muscovado sugar*; and in this state it is commonly exported from our West Indian colonies. As the molasses is very imperfectly separated from the crystallised sugar, a considerable diminution of weight takes place subsequent to the shipment, by the drainage from the hogsheads. This waste has been estimated to amount to no less than 12 per cent. The loss upon French colonial sugars used to be much greater even than this. Means have, however, been adopted of late years in some colonial sugar-works for reducing this loss.

Clayed sugar, also called *Lisbon sugar*, is raw sugar that has been subjected to a peculiar operation. The sugar is removed from the coolers into conical earthen moulds called *formes*, each of which has a small hole at the apex. These holes being stopped up, the formes are placed, apex downwards, in other earthen vessels. The syrup, after being stirred round, is left for fifteen or twenty hours to crystallise. The plugs are then withdrawn, to let out the uncrystallised syrup; and, the base of the crystallised loaf being removed, the forme is filled up with pulverised white sugar. This is well pressed down, and then a quantity of clay mixed with water is placed upon the sugar, the formes being put into fresh empty pots. The moisture from the clay, filtering through the sugar, carries with it a portion of the colouring-matter, which is more soluble than the crystals themselves. When the loaves are sufficiently purified to be removed from the formes, they are dried gradually in a stove, and crushed into a coarse powder for exportation. Claying is little practised in British plantations, from an opinion that the increase of labour and diminution of quantity of produce occasioned by it are not compensated by the improved quality of the sugar. It was however very generally practised by the French in St. Domingo. Hague's process consists in submitting the raw sugar, after being cured in the usual way, to the action of a vacuum filter. The apparatus consists of a shallow vessel, beneath which is a cavity connected with an air-pump. The bottom of the vessel is perforated with a number of small holes; and when a quantity of muscovado sugar, mixed with a little water into a pasty mass, is laid in it, upon a piece of haircloth, the air is withdrawn from the cavity beneath the sugar. The pressure of the superincumbent atmosphere upon the surface of the sugar then drives the moisture, and with it much of the colouring-matter, through the holes in the bottom of the vessel. When the sugar is sufficiently whitened, the air-pump is stopped, the sugar and molasses are removed, and a fresh charge of muscovado is applied. Another means of avoiding the loss consequent on the drainage from raw sugar during its voyage to this country, is the importation of sugar for the use of the refiner, in the form of concentrated cane-juice, containing nearly half its weight of granular sugar along with more or less molasses, according to the care taken in the boiling operations.

Before proceeding to the subject of sugar refining, it may be well to make a few observations on suggested improvements in the West Indian treatment of raw sugar. Chemists, and the better class of sugar-growers, have long known that a large amount of sugar is wasted by an imperfect management of the operations at the plantations. It is believed that 25 per cent. of the juice lodges in the cells of the megass or trash, and is lost; it ought to be extracted, but is not. Even if not, the trash might form a better fuel for the boiling-houses (where it is now used) if first dried by the surplus heat of the chimneys, &c. Dr. Scoffern, in 1847, ascertained that, in various ways, no less than two-thirds of the sugar is in some instances lost. In 1849 he introduced certain improvements, intended, by the use of new defecating agents, to increase the quantity of juice obtained from the cane, and of sugar obtained from the juice. Some of the agents used by him are poisonous however in their natural state, though innocuous in the process; and this seems to have retarded the acceptance of his method. Some inventors say that the weight of juice extracted is only 50 per cent. of the weight of the original cane, whereas it ought to be 90 per cent.; and they have devised a mode of treating the megass with hydraulic pressure, after the mill has done its work; by this means the megass becomes a flattened mass of trash, as hard and nearly as dry as a deal board. It is also believed that, by a better construction and management of apparatus more sugar and less molasses [MOLASSES] might be obtained from a given weight of juice.

Sugar-trash has been tried in England as a material from which to make paper, but without much success.

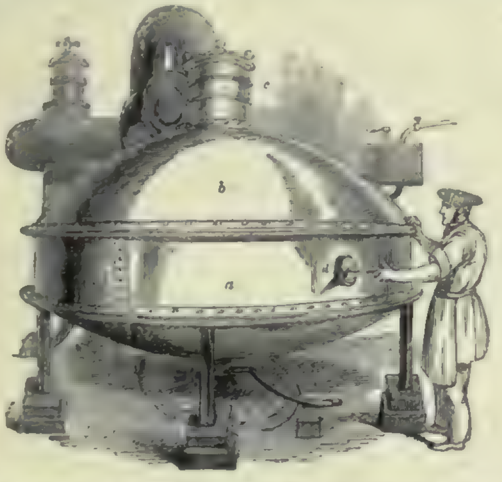
Sugar-refining.—Raw or muscovado sugar, as brought from the colonies, forms the common *moist* or *brown* sugar of the shops. The saccharine particles are always mixed with other matter, which imparts to the sugar a dark colour, a moist clammy feeling, and an empyreumatic odour. The object of the sugar-refiner is to remove these impurities, so as to obtain the sugar in the hard white semi-transparent state known as *loaf-sugar*.

The art of refining sugar, as well as that of extracting it from the cane, is supposed to have been brought to Europe from the East, probably from China; but at what time is uncertain. The Venetians are believed to have been the earliest sugar-refiners in Europe; and it is known that they practised the art before the discovery of America. The Venetians originally operated upon the coarse black sugar brought from Egypt, and followed the Chinese practice of converting it into sugar-candy before they made loaf-sugar. Stow ('Survey of London') states that sugar-refining was commenced in England about 1544. There were then two sugar-houses in London, but they yielded little profit, because there were many sugar-bakers in Antwerp who could supply refined sugar to England better and cheaper than it could be made at home. Subsequently, the commerce between England and Antwerp being stopped, these two sugar-houses supplied all England for twenty years, and became so profitable, that many other persons embarked in the business.

Few manufacturing operations have undergone more important changes than that of sugar-refining. As generally practised until within a recent period, the process commenced by mixing the raw sugar in a large open copper with lime-water, and adding to the mixture when warm a quantity of bullock's blood. The heat occasioned the serum of the blood to coagulate, and in so doing to collect most of the impurities floating in the liquor, and to raise them with it to the surface of the syrup in the form of a thick scum, which was carefully removed. This clarifying process was sometimes repeated with a fresh quantity of blood, or, as it is technically called, *spice*. When the liquor was thus rendered tolerably clear, and was partially evaporated by boiling, it was further cleansed by passing it through a filter of thick woollen cloth, which detained any particles of scum that might have been left after skimming the liquor. It was afterwards concentrated by boiling in a smaller open copper till sufficiently thick for graining; after which it was formed into loaves in the manner hereafter described. For loaves of the finest quality a second refining followed this. In the preceding section allusion has been made to the methods of separating molasses from raw sugar by the vacuum-filter and the hydraulic-press, both of which have been applied to the preparation of sugar for refining; by the latter process sugar is now capable of yielding loaves equal to double-refined by one process.

Many improvements have been effected upon the old methods of clarifying and concentrating the syrup. The raw sugar is transferred from the casks into large circular *blow-up cisterns*, in which it is mixed with lime-water. The mass is heated by steam, forced by its own pressure through small apertures in copper pipes, which are laid along the bottom and sides of the vessel; and the perfect solution of the sugar is aided by stirring with long poles. The liquor is allowed to flow from the blow-up cistern to a range of filtering-vessels in a room beneath. The filters are tall vessels six or eight feet high, of cast-iron or wood, having cisterns at top and bottom; and a number of cloth or canvas tubes, closed at their lower ends, but communicating at their upper ends, by which they are suspended, with the upper cistern. Within each of these tubes is a bag of thick close cotton-cloth, which, being much larger in diameter than the tube in which it is enclosed, is necessarily folded together. By this device a very extensive filtering surface is obtained in a small compass; and, as the liquor from the upper cistern cannot escape from the bags except by percolating through the meshes of the cloth, it becomes, as it drops into the lower cistern, very clear and transparent; most of the solid impurities remaining in the bags. On leaving the filter, the syrup, though clear and transparent, is of a reddish colour; and the removal of this tinge is effected by filtering the syrup through a mass of powdered charcoal. The application of the bleaching power of charcoal to the purification of sugar is one of the great improvements effected by modern science. Powdered animal charcoal is placed in a large square vessel, which has a perforated false bottom, to the thickness of nearly three feet. The syrup is conducted by pipes from the bag-filter to the surface of the charcoal, through which it percolates slowly; it then drops through the holes into the cavity beneath, where it is found almost colourless. In some cases, before the sugar is placed in the blow-up cistern, it is partially purified by mixing it into a pap with hot water or steam, and exposing it to drain in large sugar-moulds, similar to those used in the preparation of clayed sugar. In this case the purification may be rendered more complete by the filtration of moisture from a magma of sugar (a mass of wet sugar in a state resembling mortar), applied in the same way as that of clay in the claying process. Sometimes also a little blood is mixed with the sugar in the blow-up cistern; or, instead of it, a mixture of gelatinous alumina and gypsum, called *finings*. Other refiners use both the blood and finings.

In the concentration of the clarified syrup, which forms the next process, improvements of the greatest importance have been effected. In the old plan of concentrating the syrup in open pans, they were heated by fires to a temperature of from 230° to 250° Fahr. Many plans were contrived for rendering the application of heat more regular and controllable. It is well known that fluids will boil at a much lower temperature in a partial vacuum than when exposed to the ordinary pressure of the atmosphere; and by the happy application of this principle, Mr. Howard removed the chief difficulties attending the evaporation of saccharine syrup. The accompanying cut, which represents one of the *vacuum-pans* constructed on Howard's principle, may assist in the explanation of this admirable contrivance. The apparatus consists of a copper vessel, *a*, *b*, the several parts of which are united by flanges, with packing between the joints to render them perfectly air-tight. The middle portion, *a*, is cylindrical, from six to seven feet in diameter; and the upper part, *b*, is convex or dome-shaped. The bottom is also convex, but in a less degree. The bottom is double, the cavity between the inner and outer casings forming a receptacle for steam. The best kinds of pans have also a spiral coil of copper pipe a little above the inner bottom, by which steam may be made to circulate through the body of syrup in the pan, and thereby assist evaporation. The bottom cavity is supplied with steam generated at a low pressure; but the spiral pipe contains steam of high pressure, and consequently of great heat. There is a short broad pipe called the *neck*, rising from the dome, from which a communication is formed with an air-pump, by which the pan may be partially exhausted of air. A communication is also formed between the interior of the pan and a vessel containing clarified syrup. A quantity of liquid sugar is admitted. The air-pump continues at work during the boiling of the syrup, motion being communicated to it from a steam-engine; and by this means the sugar is enabled to boil at a temperature of only 130° to 150°, or 100° lower than that required in open vessels. To ascertain when the syrup is sufficiently evaporated, the pan is supplied with a very ingenious appendage called the *proof-stick*, the handle of which is shown as held by an attendant. It consists of a tube extending into the pan, and terminating in a peculiar kind of valve, so formed that, by turning a rod inserted in the tube, a sample of sugar may be drawn out without admitting air into the vessel. The sample thus obtained is tried by the *touch*, as described in explaining the process of evaporation in the West Indies; and when it appears to be in a satisfactory state, the sugar is allowed to flow, through an opening in the bottom of the pan, into a granulating-vessel in a room below.



The practice of boiling the syrup at so low a temperature has occasioned a curious difference in the next process, which is that of granulating the concentrated liquor. In the West Indies, the vessels used for this purpose are called *coolers*, because the syrup is brought down to a lower temperature than in the boiling-coppers. The corresponding vessels used in refining sugar upon the old plan were similar to these, and were called by the same name; but when the method of boiling at a low temperature is adopted, the granulators become *heaters* instead of *coolers;* the sugar, when placed in them, being raised to a temperature of 180° or 190°. This is done by the admission of steam into a cavity surrounding the granulating-vessel, a shallow open copper or pan, in which the thick pulpy mass is stirred quickly to promote the granulation.

From the granulators the sugar is transferred, by means of copper basins or pans, into moulds of a conical form, usually of iron. These moulds have orifices at their points, which are stopped up before they are filled with sugar. They are arranged with their open bases uppermost; and immediately after the sugar is poured in it is stirred round, to diffuse the crystals equally through the semifluid mass. They are then left for several hours, that the sugar may become solid: after which they are removed to another room; and, their points being unstopped, they are set in earthen jars, that the uncrystallised fluid may drain from them; or the same purpose is effected by placing them in racks, with gutters to receive the syrup. This syrup is re-boiled with raw sugar, so as to yield an inferior quality of sugar; and when all the crystallisable matter has been extracted from it, the remainder is sold as *treacle*. It was formerly usual to "clay" the loaves in order more thoroughly to remove the molasses; but this process is abandoned by most refiners for the superior method introduced by Mr. Howard of cleansing the loaf by causing a saturated solution of sugar in water to percolate through it. When the loaf of sugar is thoroughly purified by the repetition of this process, and is sufficiently dry, it is turned out of the mould; the base being scraped to an even surface, and the apex applied to a kind of lathe, in which any part that may be slightly discoloured is cut off, leaving the end clean and smooth. The loaves are finally dried in an oven heated by steam-pipes to a temperature of 130° or 140°, and then wrapped up in paper for sale.

It is needless to follow the processes by which the syrups and other refuse of the best sugar are converted into sugars of inferior quality, which are either sold as cheap loaf-sugar, or formed into large coarse loaves called *bastards*, which are crushed into powder for sale. It has been asserted that about two-thirds of the molasses found in the moulds under the old system were formed by the intense heat employed in concentrating the syrup; a loss which is now, in a great measure, obviated. The effect of these improvements in diminishing the price and consequently increasing the consumption of refined sugar, is also very important; the cost of refined sugar being now only about 20 per cent. greater than that of raw sugar, although formerly the difference of price was as much as 40 per cent.

In the preparation of refined sugar, as in that of raw, many improvements have recently been introduced; but none equal in importance to Howard's capital invention of the vacuum pan. The chief of them is the draining of the sugar-loaves by centrifugal motion, on the system now so largely adopted in many branches of manufacture. [DRYING MACHINES.] Several sugar moulds, with crystallised wet sugar in them, are arranged in a horizontal circle, each with its open apex outwards; the frame containing them is made to rotate 800 times in a minute, and the centrifugal force thus generated drives all the moisture out of the sugar and out of the mould. Or the wet mass may be put at once into a centrifugal machine, and whirled round until it becomes a nearly dry white powder. In either case there is a great saving of time over the old method. Van Goethem, a Belgian sugar refiner, has been the chief agent in bringing about this improvement.

Sugar-Candy.—This is the only kind of refined sugar made in China and India; and is made of the finest quality by the Chinese, who export it in considerable quantities. Two sorts are met with at Canton, called, respectively, Chinchew and Canton; the former being the produce of the province of Fokien, and the latter of that of Canton.

Of these, the former is by far the best. Chinese sugar-candy is consumed, to the almost total exclusion of other sugar, by the Europeans at the settlements in the East. The process of making it is briefly described under CANDY.

Beet-root Sugar.—The process of manufacturing sugar from beet is described under BEET. The manufacture was commenced in Europe chiefly through the high price of colonial sugar, owing partly to war and partly to taxation. The early attempts were disastrous: but within the last few years the manufacture has greatly extended. Stollé, of Berlin, estimated the quantity of beet sugar exported from the countries where it was made, at about 2,300,000 cwt. annually; but this affords no index to the quantity *made* and *consumed* in those countries. It is known that 20,000,000 centners of beet-root have been used for the manufacture in Germany alone in one year. In France, also, the number of beet-sugar manufactories is very large. The relative advantages and disadvantages of beet-sugar have long been, and still are, a matter of controversy. Stollé claims for beet-sugar made in Europe, over cane-sugar made in slave countries, the following advantages: superior intelligence and skill of the operatives; superiority and easy repair of machinery; ready intercourse of the manufacturers with chemists and mechanical inventors; the presence of the owners instead of entrusting the management to agents; a ready supply of labour and skill of various kinds; and a climate less likely than that of tropical countries to produce fermentation in the saccharine juice. Very favourable balance sheets have frequently been put forth by beet-sugar makers; but these, like many other kinds of balance sheet, require to be received with caution.

We may here add a few words concerning sugar from the *maple* and the *Sorghum saccharatum.*

Maple-sugar is made in Canada and the United States. The sap is obtained by boring holes in the trunk of the maple-tree, in a direction inclining upwards, with an augur about three-quarters of an inch in diameter: the depth of the holes being such that they may penetrate about half an inch into the alburnum, or white bark, as the sap is found to flow more freely at that depth than at any other. Tubes of elder or sumach are inserted in the holes, so as to project a few inches from the trunk; their outer ends being cut so as to form small troughs, along which the sap trickles into receptacles placed beneath them. The season for collecting the sap extends from the beginning of February to the middle of April. Though collected in frosty weather, the tendency of the juice to fermentation renders it desirable to boil down the sap within two or three days at furthest from the time of its extraction. This is done in very rude apparatus, which is carried to the encampment formed by the sugar-makers. The syrup is thus brought to about one-third of its original bulk, the scum which rises being removed. White of egg is sometimes used as a clarifier; and occasionally a little butter or fat is thrown in during the last boiling. The molasses are separated, though mostly in a very imperfect manner, by filtration. The concreted sugar is said to be equal in taste to cane-sugar, and to sweeten as well. It is seldom refined, but is capable of being made equal to loaf-sugar from the cane.

The *Sorghum saccharatum*, or Sugar Grass, has lately become an object of attention. Seeds were brought from China, and distributed in France, Belgium, Germany, England, and the United States. Some were sown in a market-garden at Streatham, in October, 1858; the plants grew to a height of 10 feet; and the juice was said to contain 13 per cent. of saccharine matter. Dr. Scoffern even asserted that every acre of inferior sandy land in England might be made to yield 4½ tons of sugar from this source; that in bad years the plant might be sliced in November, dried, and used for fodder, instead of turnips; and that it is superior to the white beet and the sugar-maple as a source for sugar. This high encomium, however, has not been verified. The plant, nevertheless, is more easily cultivated than the sugar-cane, and over a wider variety of soil; and as the juice is contained in stems capable of being sliced, there is no occasion for a sugar-mill. On the other hand, Dr. Hayes, of the United States, from experiments made in 1857, found that the syrup would not crystallise properly: whence he inferred that the plant secretes, not true sugar, but a semi-fluid glucose. At any rate, the plant is worthy of further attention in Europe. It is said that the first seeds were brought from Shanghai to Paris in 1851, that all died but one, and that all the plants of the *Sorghum* now being grown for this experiment in Europe and America are the produce of this one seed.

Sugar-Trade.—It is not known how much sugar is made in the world. Stollé, in 1853, put down the quantities of cane-sugar *exported* from the several countries as follows:—

East and West Indies (British)	7,030,000 cwts.
French colonies	1,290,000 ,,
Dutch colonies	1,300,000 ,,
Spanish colonies	6,650,000 ,,
Danish colonies	150,000 ,,
Brazil	4,000,000 ,,
United States	2,730,000 ,,
	23,150,000 ,,

To which he added about an equal quantity consumed in those same countries. He also put down in his tabulation, 3,300,000 cwt. of beet-sugar, 2,000,000 of palm-sugar, and 400,000 of maple-sugar. If these estimates are approximately correct, the total sugar product would be over 50,000,000 cwts. Mr. M'Culloch has expressed an opinion that, in 1858, the produce of cane-sugar all over the world was 1,250,000 tons, equal to 25,000,000 cwts.—an estimate so much lower than that of Stollé for 1853, as to show that the authorities rely on very different data. Mr. M'Culloch credits Cuba with one-third of all the cane-sugar grown in the world.

In 1661 a duty amounting to 1*s.* 6*d.* per cwt. was imposed on the importation of British plantation sugar in England; and in 1669 the duty was doubled. This gradually rose to 30*s.* early in the present century, from which it fell to 24*s.* in 1833. From 1793 to 1808, the duty on East India sugar was 37 and 38 per cent. ad valorem, and afterwards was 11*s.* and 8*s.* the cwt. higher than the duty on West India; but by an act passed in 1836, the duties were assimilated by the reduction of East India sugar from 32*s.* to 24*s.* the cwt. The duty on foreign sugar varied from 60*s.* to 63*s.* until about 1844.

Fluctuations in price, and the domestic circumstances of the country, occasion great diversities in the consumption of different years. Thus, with the low price of 1831, the consumption was greater than in 1839, notwithstanding the population of Great Britain had increased nearly 2,000,000. The annual consumption averages above 20 lbs. per head for England and Scotland, and would probably be 50 lbs. if a great reduction were to take place in the price. In France the annual consumption averages 5 lbs. per head; in the states of the German League, above 4 lbs.; and in the whole of Continental Europe, about 2½ lbs.

The quantity of sugar produced in the West Indies has fluctuated greatly since the emancipation of the slaves. The equalisation of the duty on East India sugar in 1836 gave a stimulus to the cultivation of the sugar-cane in the East Indies, and the import of 1840 exceeded all expectation, being 1,066,032 cwts., or above 53,000 tons. The scarcity of 1840 was so great that 2316 cwts. of foreign sugar were entered for home consumption, paying a duty of 63*s.*, or 39*s.* the cwt. more than sugar from British possessions. The sugar of Brazil, Cuba, and other foreign countries is chiefly exported to the Continent, where the price is on an average from 10*s.* to 20*s.* the cwt. lower than in this country.

In 1844 a great change was effected in the sugar duties, whereby foreign sugar might, under certain circumstances, be imported at a duty of 34*s.* instead of 63*s.*, and in some favoured instances (to encourage free instead of slave labour) as low as 23*s.* 6*d.* Sugar from foreign slave states was still to pay 63*s.* Sugar from British possessions was to pay 14*s.* to 21*s.*, according to quality. By acts passed in 1846 and 1848, the duties on British and foreign sugar were gradually to approach equality, the equalisation to be completed in 1854, at which date all sugars would pay from 10*s.* to 13*s.* 4*d.* per cwt., according to quality. Between 1854 and 1858 the duties were slightly raised, to meet a war expenditure; during this interval, the lowest duty on the lowest kind was 11*s.*; and the highest duty on the highest kind, 17*s.* 6*d.* By the tariff of 1860, the duty was still again slightly raised, ranging from 12*s.* 8*d.*, for common moist, to 18*s.* 4*d.*, for best refined: cane-juice paid a duty of 10*s.* 4*d.* These duties are the same, whatever country the sugar may be brought from.

Without taking note of the quantity re-exported, the following gives the quantity of sugar imported for home consumption, and the duty raised from it, in six different years, situated respectively five years apart:—

	Entered for Home Consumption.	Amount of Duty.
1833	3,600,000 cwts.	£4,400,000
1838	3,900,000 ,,	4,700,000
1843	4,000,000 ,,	5,100,000
1848	6,100,000 ,,	4,600,000
1853	7,300,000 ,,	4,100,000
1858	8,500,000 ,,	5,800,000

The above quantities are given in round numbers; but to illustrate the present state of the trade, the figures for 1860 will here be given in more detail:—

	Imported.	Home Consumption.
Unrefined, 1st quality	86,516 cwts.	48,505 cwts.
,, 2nd quality	4,743,286 ,,	3,464,999 ,,
,, 3rd quality	4,037,784 ,,	5,184,093 ,,
Total unrefined	8,867,586 ,,	8,697,597 ,,
Refined and sandy sugar	245,041 ,,	266,064 ,,
Cane juice	18,286 ,,	12,026 ,,
Molasses	646,765 ,,	559,953 ,,
	9,777,678 ,,	9,535,640 ,,

It will thus be seen that the home consumption of sugar very nearly equals the imports, leaving only a small quantity for re-exportation. The computed real value of the whole (minus the duty) was about 18,000,000*l.*

SUGAR, PROPERTIES OF. Sugar is a proximate principle, chiefly of vegetables, but also sparingly of animals of the class Mammalia. It presents considerable varieties, according to the source whence it is obtained, and is distinguished into those which are capable of undergoing the vinous fermentation, and into those which are not; also into those which can assume a definite crystalline form, and those which cannot; but sometimes these two kinds co-exist in the same sort, as in the sugar from the sugar cane, which yields both the finest crystals and likewise molasses or treacle. It almost invariably exists in a dilute and liquid state in plants, but it occasionally exhibits a crystalline form in the flower of certain plants, such as the *Rhododendron ponticum*, the *Strelitzia Reginæ*, and *Eucomis punctata*. Sugar is the great principle by which rapidly-growing succulent parts of plants and seeds, when they germinate, are nourished. Hence it is produced in large quantities in such seeds as contain starch, when excited to germinate, as may be observed in the process of malting, which up to a certain stage is exactly that of the germination of the seed. Under these circumstances, seeds which are insipid from the bland nature of the starch which they contain become sweet. By this means many seeds which are regarded as little suited for the nourishment of man may be made to contribute to his support, by merely steeping them in water till they sprout. A similar transformation of starch into sugar takes place in the ripening of many fruits. Thus the fruit of the banana, or plaintain, which, when gathered green, abounds in starch, if allowed to ripen on the stalk is destitute of starch, and yields much gummy and saccharine matters. The same happens when the palms are about to flower, as all the starch in their lofty stems is rapidly transformed into sugar; and hence the sago-palm (*Sagus Rumphii*, &c.) and the *Mauritia flexuosa* (sago-palm of the Orinoco) are cut down just when the flower-buds begin to appear, to obtain the sago they contain. In other palms the flower-buds are allowed to protrude, and a wound being made in the spatha, a large quantity of a sweet fluid distils, which may either be concentrated by boiling, when sugar is deposited, or the liquid may be fermented, and so yield the *toddy* called *palm wine*. If these, or the sugar-cane, maize, or our common esculent roots, parsnep, skirret, carrot, or beet, are allowed to flower, all the gummy and saccharine matters disappear from the roots or stem. The transformation of starch into gum and sugar is effected by a principle called *diastase* [FERMENT], which is so powerful, that "one part of it is sufficient to render soluble the interior portion of two thousand parts of starch, and convert it into sugar." Wherever buds are lodged, there the elements of diastase are placed, to come into play, when they begin to sprout, and supply them with food in a state of solution, as is the case with the buds or eyes of potatoes.

Many seeds, before they are ripe, contain a saccharine substance, which is changed into starch when fully ripe, but which again becomes sugar in germinating, such as the garden pea. Many stems of grasses are sweet at an early stage of their growth, but become insipid at a later period. This influences greatly the nutritive powers of these grasses, according to the stage of growth when they are cut down and made into hay. (See appendix to Davy's 'Agricultural Chemistry.') Those which have been allowed to become too ripe are often restored to a proper state by the fermentation (*heating*) which occurs after the hay is stacked; but this is sometimes so violent as to consume the rick.

The starch lodged in the stem of certain trees in autumn is converted, by the ascending sap in spring, into sugar, with great rapidity. This is the case with the *Acer saccharinum*, or sugar-maple, and many other species of that genus which are tapped in February.

The same is the case with the ascending sap of the birch-tree, but this does not contain sufficient sugar to permit the concentration of it; there is enough however to undergo the vinous fermentation, and thereby furnish the agreeable beverage called *birch wine*.

Next to the sugars from the cane and beet-root, among those which are crystallisable and capable of fermentation, the most important is the *granular* sugar obtained from a great variety of sources. It exists in considerable quantity in the juice of grapes, and hence the name *grape sugar*, which should be limited to this particular variety, is sometimes extended to the whole class of krummel sugars. It forms a constituent of a great many fruits, not merely fleshy, such as pears, cherries, peaches, melons, dates, figs, grapes, on which last two it forms a white incrustation when these are dried, but in chesnuts, when produced in warm regions. It exists in the nectaries of many flowers, and is collected by the bees; hence honey is only one of the kinds of this sugar. Though harmless in probably all instances to the bees, from whatever plant collected, it not unfrequently has a poisonous influence over human beings, when it has been collected from poisonous plants, such as Rhododendrons and their allied genera.

Granular sugar is readily formed by the action of dilute sulphuric acid on starch, or sugar of milk, or the *bastard* sugar which remains after the finest refined sugar has been procured from the cane or beet-root sugar. Lignin, or anything containing or formed from it, such as saw-dust, linen-rags, or paper, may be likewise transformed into granular sugar. It is likewise the kind of sugar formed during the germination of seeds. Lastly, it is that kind of sugar which is formed by a perverted action of the digestive and assimilating organs in the disease termed *diabetes mellitus*. [DIABETES.] All these varieties taste less sweet than the cane-sugar, and also differ among themselves; thus grape and honey sugar are sweeter than that from starch, while starch sugar is sweeter than that obtained from juniper berries. All of them contain less carbon and more water than the cane sugar, and may be regarded as hydrates of sugar.

Sugar, which, though with difficulty crystallised, is referred to this section, exists in many fungi or mushrooms, especially of the genus Agaricus. While it contributes to their nutritive properties, it most likely proves one source of the poisonous qualities they sometimes possess, as it is occasionally transformed into oxalic acid. Masses of crystals have been observed on the cap of a mushroom, some of which were sugar, while others were oxalic acid. Free oxalic acid is found in the *Polyporus sulphureus*, Bull., which is most likely formed at the expense of the sugar.

The only uncrystallisable sugar which is capable of fermentation is the syrup which remains after the refining of the cane and other sugars. It receives the name of molasses, and is used in medicine under the name of Sacchari faex, which is preferable to that of *theriaca*, as this might lead to confusion with a poisonous compound which bears a similar name. Molasses are largely employed for the distillation of rum.

The kinds of sugar unsusceptible of fermentation are, the sugar of milk and mannite; yet sugar of milk, when by the action of dilute sulphuric acid it is converted into granular sugar, is as susceptible of fermentation as any of the above-described. In other respects it conducts itself like common sugar, except that with nitric acid, besides oxalic acid, it forms saclactic acid. It is procured from whey, either simply by evaporating to dryness (*saccharum lactis inspissatum*), or by crystallising it. It is frequently separated from the curd by the addition of a great many substances, which can coagulate this, such as alum, vinegar, tamarinds, and mustard, and in certain diseases these medicated wheys are much recommended.

Sugar of milk has little sweetness, but a hot solution of it tastes much sweeter than the dry sugar. Sugar of milk is much used by the followers of homœopathy as the material of their dynamised globules.

Manna sugar constitutes the greater portion of the manna which flows from the *Ornus europaea* and other ashes in the south of Europe, the bark of the olive-tree, many species of pines, the root and leaves of celery, the bulb of the common onion, and in the rhizome of the *Triticum repens*, or couch-grass. The sweet juices of many plants, such as beet, carrots, &c., when long exposed to the air, generate manna sugar by a partial fermentation. To prevent this is one of the great objects in the manufacture of beet-root sugar; hence the necessity for speedily concentrating and purifying this juice. To this variety of sugar probably belongs Cynodon, which exists in the root of *Digitaria* (*Cynodon*) *Dactylon*. And also the principle called *canellin*, obtained from *canella alba*.

The principle called glycyrrhizin, obtained from the liquorice-plants, and the analogous principle from the leaves of the abrus precatorius, and the root of the common polypody fern, probably belong here, as well as sarcocollin, which exists both in *Penæa mucronata*, *P. Sarcocolla*, and in the polypody. Picromel, or the sweet principle which exists in the bile of mammals and birds, is probably a variety of sugar, though unsusceptible of fermentation, and ought to be considered in conjunction with it, from the share it may have in augmenting the sugar in diabetes. (See Experiments of Claude Bernard.)

In treating of the dietetical properties of sugar, it is necessary to view it in a variety of conditions. In temperate climates sugar is regarded as a luxury, one indeed which is nearly indispensable; but in tropical countries it is a universal article of subsistence, partly as real sugar, and partly, and more generally, as it occurs in the cane, which is either simply chewed or sucked, or softened by previous boiling. In this state it is eminently nutritious. It has been called "the most perfect alimentary substance in nature," and the results, in the appearance of the negroes, during the cane harvest, notwithstanding the increased severe toils of that season, seem to confirm the statement. They almost invariably become plump and sleek, and scarcely take any other food while the harvest lasts; even the sickly revive, and often recover their health. The crude plant, or the newly expressed juice, contains water, sugar, gum, green fecula, extractive, gluten, acetic and malic acids, acetates of lime and potash, supermalate and sulphate of lime, and lignin. It is the object of the various processes to which the juice is subjected, both in the countries where it is produced and where it is refined, to separate the sugar from the other ingredients, some of which dispose it to ferment and spoil, and others are obstacles to its crystallising. (See a valuable paper by Messrs. Guynne and Young, in 'British Annals of Medicine,' vol. i., p. 778; and ii., p. 42, where they enumerate tannic acid and oxide of iron among the ingredients of raw sugar). By the removal of such of these principles as contain azote, especially the gluten and green fecula, the nutritive power of sugar is sensibly diminished.

However harmless the use of saccharine vegetables may be to persons in health, there cannot be a doubt but that in some instances they are extremely hurtful. "The derangement or partial suspension of the converting the saccharine principle in man into the albuminous or oleaginous, not only constitutes a formidable species of dyspepsia, but the unassimilated saccharine matter in passing through the kidneys gives occasion to the disease termed *diabetes*." The blood of a perfectly healthy individual contains no appreciable quantity of sugar; but in diabetes, sugar has been repeatedly ascertained to exist in the sanguiferous system,—a fact unequivocally demonstrating that the assimilating organs had failed to convert the saccharine aliment into the constituent principles of the blood. Oxalic acid is neither found in the blood nor in the urine in a state of health; but in certain forms of disease probably exists in both fluids. Lactic acid, when in excess, which forms one of the most troublesome kinds of acidity in the stomach, and the frequent concomitant of *bilious attacks*, is likewise the result of such mal-assimilation generally of the saccharine matter, though occasionally of albuminous matters. The prohibition of articles of a decidedly saccharine nature from the diet of diabetic patients becomes absolutely necessary. Not only sugar in its crystallisable states must be prohibited, but those fruits which contain it. A single peach or pear has occasionally brought back the disease in all its severity. Even those starchy or farinaceous matters which we have seen to be convertible into sugar must be avoided, especially potatoes, the starch of which is, of all others, the most easily transmuted into sugar which is of the same nature as the diabetic sugar.

The abuse of sugar is to be avoided by persons disposed to the oxalic acid diathesis; and persons of a bilious habit should use it with great moderation, as also those with tendency to rheumatism. (See Prout.)

Sugar, though prone to fermentation when in a dilute state, possesses when concentrated great antiseptic properties, and is extensively employed to preserve both animal and vegetable substances from decomposition. Sometimes the sugar existing naturally in many fruits is sufficient to ensure their preservation, as in figs, raisins, and other dried fruits; especially if the season has been bright and warm, when more sugar is elaborated. In other cases sugar is added, as in many preserves and jellies. Sugar added to meat, fish, &c., renders less salt necessary for keeping them, and preserves more of the natural taste and flavour. Many medicinal substances, as well as flavours and colouring principles, are preserved by means of sugar. [SYRUPS.] Sugar, from the readiness with which it reduces to a metallic state those bases which have a weak attraction for oxygen, has been proposed as an antidote in cases of poisoning with copper, corrosive sublimate, &c. It is to be doubted whether syrup is adequate to effect the reduction at the temperature of the stomach. On the other hand, sugar yields oxygen to those substances which attract it strongly, such as phosphorus; hence nothing so quickly and certainly revives a fire nearly extinct as throwing a little brown sugar on the embers. Sugar burnt at a low temperature constitutes *caramel;* one part of this dissolved in four parts of water constitutes the liquor (improperly called *tinctura*) sacchari tosti, which is employed as a colouring-matter for many liquids, especially for the dark-coloured sherries and other wines.

Refined sugar is much employed for the administration of volatile oils, constituting oleo-saccharums. Finely powdered white sugar sprinkled upon ulcers with unhealthy granulations acts as an escharotic.

The term sugar has been applied to some substances on account of their sweet taste, which are widely different from real sugar, and possess even poisonous properties, such as acetate of lead, or *sugar of lead*. Oxalic acid, another very poisonous substance, is often called, from being prepared from sugar, *acid of sugar*, and therefore thought to be harmless. Fatal accidents frequently result from this mistake. [OXALIC ACID.]

SUICIDE is the term usually applied both to the act of self-destruction and to him who commits it. As a subject of medical investigation, the most important distinctions among cases of suicide are founded on the circumstances which lead to its commission; and of these there are two chief classes: in one, a man is led to disregard his life for the sake of something for which his death is necessary; in the other, he is depressed by an evil more intolerable than the act of dying. But whichever of these be the motive, it may act in two different ways, and the suicide may be, as M. Esquirol has said, either acute and involuntary, or chronic and prepense. Or, again, suicides of all kinds may be divided (and this is probably the most practical method) according to the condition of the mind which has preceded the act, and which in each case constitutes the disposition to self-destruction.

In many cases this disposition is only a part of the general perversion of the judgment in complete insanity: it thus exists in certain maniacs in combination with many other signs of a diseased mind. Some are merely melancholy; some are carried on by illusions which lead them, as if unintentionally, to suicide; some have sensations which they imagine may be cured by such violence as proves fatal; some are driven to the act by commands which they imagine they have received; some destroy themselves at the commencement of insanity, when they are conscious of the malady which threatens them; others, in their convalescence, in horror at the excesses which they have committed, or at the mere thought of having been deranged.

There are also cases of monomania in which almost the only indication of insanity is the desire for self-destruction, excited by an illusion respecting some melancholy event, or by some fancied command. A peculiar and very terrible variety of this monomania, is that in which the desire for destruction leads the patient to take the lives of others, against whom he bears no ill-will, before he attempts his own. Many instances of this homicidal monomania, as it is called, are recorded.

There are conditions of the mind which are not called insanity (in the ordinary acceptation of the term), but which do not less strongly predispose to suicide. Such is especially that named *ennui*, or *tædium vitæ*, for which, though it is thought by foreigners to be so common in England that Sauvages has called it "melancholia Anglica," we have in our language no term except the very inexpressive one, *spleen*. Many circumstances give rise to this state of mind; most commonly it is the consequence of a want of occupation, or of a sudden transition from a state of active exertion in business or in pleasure, to one of voluntary or compelled repose; or it results from the difficulty which those who have long lived in the excitement of frivolous pursuits find in maintaining it by new objects of desire.

The state of the hypochondriac, though of somewhat the same kind, is less dangerous. He is persuaded indeed that his sufferings are irremediable, and that death would be a great relief to him; he even often talks of committing suicide; but he is as irresolute in the use of the means of death as he is anxious in the use of those for prolonging life; and if he do at last, after repeated postponements, attempt to destroy himself, the attempt is generally, through want of determination, abortive, and he again sinks into the same despondency and inactivity.

In all these cases the suicide is of the chronic or prepense kind; and in all, the condition of mind which precedes it is connected with a perversion of the judgment so obvious, that no reasonable person could hesitate to regard it as insanity. Whatever ingenuity of plan may have been shown in the preparation for the act, very few persons would deny that, under similar external circumstances, it would not have been committed by a sane man; and this is true of the great majority of prepense suicides in the present day.

In the acute or involuntary suicides, the predisposing condition of the mind is the result of circumstances which act rapidly, and pervert a judgment which, before their occurrence, might be deemed sound. Suicides of this kind are probably less frequent than those of the preceding; but they are usually more shocking, and attract more attention; they are especially common in large towns, or wherever men pursue great objects at great hazards. For instance, a loss of money or of honour, the failure of an ambitious enterprise, jealousy, and many afflicting events, are enough at once to deprive a man of tender sensibility of the power of just reflection, and to make him think that death is not so bad as the misery which he must undergo. On the spur of the moment of anguish he destroys himself. Similar circumstances impel a man of colder temperament, or of a braver disposition, more slowly to the same end. The one may for a time endure passively his disgrace; the other may have courage at first to bear up against it; but at length the judgment is in both alike perverted, and the same state of mind is produced which urges others to immediate self-destruction.

Lastly, there are examples in which suicide is committed with perfect coolness, being adopted, after due deliberation, as the most judicious course which, in the circumstances of the case, and as far as the knowledge of the individual enabled him to judge, could be followed. Such are many of the cases in which men, finding themselves afflicted with incurable and painful diseases, have shortened that which they believed would be a miserable life; and of the same class are the suicides committed in accordance with national custom, or superstition, or from patriotic motives. The cases of this class are not proper subjects for medical consideration, for in these there is no disorder of the mind. The act is committed either without deliberation, in obedience to custom or authority; or, when deliberation is used, the conclusion is only the necessary result of the error in the premises.

Such are the states of mind which most commonly predispose to suicide, and the circumstances which produce them. The character of the act itself usually corresponds closely with that of the mind by which it is urged. By those who commit it after deliberation, the means employed are almost always successful; so they are when men who have endured affliction for some time, at last sink under it. But when suicide is attempted under the sudden impulse of the fear of disgrace, the endeavour is often abortive; the means chosen are insufficient, or they are awkwardly employed; and it deserves notice, that the attempt generally seems to be the acme of the frenzy; for if it be unsuccessful, it is very rarely repeated, and often he who has made it, in the next minute seeks assistance, and bitterly repents his folly.

It is a generally received opinion that cold foggy climates favour the development of the suicidal disposition; but in Holland, the climate of which is very similar to that of Great Britain, the proportion of suicides is lower than in any other countries with milder climates; and that many circumstances are capable of counterbalancing whatever influence climate may have, is proved by the number of suicides in the same country having varied considerably in different periods. It has also been shown that the number of suicides, in proportion to the population, is greater in France than in England. In the year 1858, in England and Wales the total number of suicides was 1257, of whom 921 were males, and 336 females, or 1·6 in 20,000 of the whole population, or 1 in 450 of the deaths.

In accordance with the same general opinion, it is commonly said that suicides are more frequent in the latter part of the autumn than in any other season; but statistical inquiries would seem to indicate that the kind of weather which is most favourable to the suicidal disposition is rather that of long-continued heat and drought. The tendency to suicide varies greatly among persons of different stations and occupations. In a letter from Mr. Farr to the registrar-general, this tendency was shown to be "least among persons who carry on occupations out of doors, and greatest among artisans who are weakly from birth, are confined in-doors, have their rest disturbed, or have little muscular exercise."

From what has been said of the variety of causes which may engender or encourage the disposition to suicide, it must be manifest that no general account can be given of the morbid conditions of the body, or of the brain, which accompany the mental disturbance. Many facts relating to this part of the subject have been related; but as yet they are unconnected by any generalisation. We may therefore proceed at once from the causes to the treatment of the suicidal disposition.

Here also what has been said of the one may serve for a guide to the knowledge of the other. With respect to the treatment of those among the insane who exhibit a tendency to self-destruction, there can be no other deviation from the ordinary treatment of insanity than that which consists in the careful removal from them of all means by which their intentions may be accomplished. Both for these and for those who show no other sign of insanity than their desire for death, the most successful remedy is the giving full occupation for the time; this is indeed essential to the safety of all who show any disposition to suicide. The occupation moreover should be one which will carry the mind as far as possible from the subjects on which it is morbidly sensitive, or on which it has been accustomed to dwell too intently. Above all, a person suspected of an intention to commit suicide, should be kept carefully from the contemplation of histories of self-destruction. Numerous instances have proved that the tendency to imitate the acts of others operates as forcibly in producing suicides as in encouraging the most trivial fashion. For all cases of imitative suicide there is a plain preventive means which should never be neglected, namely, the fear of being disgraced after death; and that this operates forcibly in deterring men from suicide, is a sufficient proof of the imprudence of the opinion which regards suicide as affording by itself sufficient evidence of the insanity and irresponsibility of those who commit it.

SUICIDE, in Law, is death caused by the act of the party dying.

A rescript of Hadrian expressly directed that those soldiers who, either from impatience of pain, from disgust of life, from disease, from madness, from dread of infamy or disgrace, had wounded themselves or otherwise attempted to put a period to their existence, should only be punished with ignominia ('Dig.,' 49, tit. 16, s. 6, 'De Re Militari'); but the attempt of a soldier at self-destruction on other grounds was a capital offence; and those who, being under prosecution for heinous offences, or being taken in the commission of a great crime, put an end to their existence from fear of punishment, forfeited all their property to the Fiscus. ('Dig.,' 48, tit. 21, s. 3.) Suicide was not uncommon among the Romans in the later republican period; and it became very common under the emperors, as we see from the examples in Tacitus, and in the younger Pliny, who mentions the case of Corellius Rufus ('Ep.,' i. 12), Silius Italicus (iii. 7), Arria (iii. 16), and the woman (vi. 24) who succeeded in persuading her husband, who was labouring under an incurable disease, to throw himself, tied to her, into a lake. [SILIUS ITALICUS, in BIOG. DIV.] Except in the cases mentioned in the two titles of the 'Digest' above cited, suicide was not forbidden by the Roman law; nor was it discountenanced by public opinion.

Suicide, by the law of England, is a crime attended by some of the consequences attached to felony. It is called, in law, though incorrectly, *felonia de se*. A *felon de se* then is a person who being of years of discretion and in his senses, destroys his own life, either intending to do so, or intending to do some other act of a character both unlawful and malicious; the legal effect of which is a forfeiture to the crown of all the personal property which the party had at the time he committed the act by which the death was caused, including debts due to him. Though the crime is called felony, it was never attended with forfeiture of freehold, and never worked any corruption of blood. But formerly the crown was entitled to the year, day, and waste of the freehold lands of a self-felon; as we find that in 1289 the widow of Aubrey or Albert (Alberici) de Wytelesbury gave 300*l.* to the king (Edw. I.) to have all the goods and chattels of her husband, "a felon by drowning himself," saving to the king the year, day, and waste of Aubrey's lands and tenements. (2 Madox, 'Exch.,' 347.)

The fact that a self-felony has been committed is ascertained by an inquest or inquisition taken before the coroner or other officer having authority to hold inquests, upon view of the dead body, and examination of witnesses in the presence of a jury, summoned, as in other cases, to inquire into the cause of a sudden or violent death. [CORONER.]

Where a self-felony is found by the inquisition, the jury ought also to inquire and find whether the party had any, and, if any, what goods and chattels at the time when the felony was committed. But an omission in this respect may be supplied by an inquisition taken by the sheriff under a writ De melius inquirendo, or "further inquiry." The property in the self-felon's goods, upon being found in either of these modes, is vested in the crown with relation to the time of the felony, so as to make any intermediate dealing with the property void as against the crown.

The crown takes the property of the felon subject to no liability in respect of his debts or engagements. But upon a memorial presented to the treasury by a creditor, a warrant is generally obtained, authorising the grant of letters of administration to such creditor, who, upon such grant being made, acquires the ordinary rights, and becomes subject to the ordinary liabilities of a personal representative.

It was formerly usual for the crown to make grants to its servants and favourites of the property arising from these and other forfeitures. These grants were either of particular forfeitures, or of forfeitures accruing within a particular district. Grants of the latter description were usually made in fee simple, and many such grants are still in force in various parts of England.

The finding of the jury is not conclusive either as to the fact of self-felony or as to the property of the deceased; and all persons interested in controverting any part of the finding may plead to the inquisition, and contest its insufficiency by a demurrer, or deny its truth by a traverse. The issues, of law or of fact, raised upon such pleadings, are disposed of as in other cases. Formerly coroners returned their inquests into the court of King's Bench, in order that process might issue against those who made seizures, set up claims, or withheld property or debts in derogation of the rights of the crown. But since the 4 & 5 Will. and Mary, c. 22, that practice has been discontinued; and the course now is, for any party who considers himself aggrieved by the finding of the coroner's jury, to remove the inquisition by Certiorari into the court of Queen's Bench, when if in consequence of some legal defect the inquisition cannot be supported, the court will quash it without putting the party to the expense of a demurrer. If however the inquisition be good in substance, the coroner may be ordered to amend defects in form.

Neither self-felony nor any other crime can be committed by a child who has not attained years of discretion; nor can it be committed by a person who, by disease or otherwise, has lost, or has been prevented from acquiring, the faculty of discerning right from wrong. A tendency to self-destruction is common in several species of insanity, and the connection between the morbid affection and the act of violence which occasions death may often be very distinctly traced. It not unfrequently happens however that cases arise in which it is nearly impossible to determine whether the act is to be ascribed to a diseased state of the mental faculties, or to passions which are not under the ordinary restraint.

At common law, which in this respect follows the canon law, a person found by inquest to be felo de se is considered as having died in mortal sin; and his remains were formerly interred in the public highway without the rights of Christian burial, and a stake was driven through the body: but by the 4 Geo. IV., c. 52, the coroner or other officer by whom the inquest is held is required to give directions for the private interment of the remains of any person against whom a finding of felo de se shall be had, without any stake being driven through the body, in the churchyard or other burial-ground of the parish in which the remains of such person might by the laws or customs of England be interred, if the verdict of felo de se had not been found; such interment to be made within twenty-four hours from the finding of the inquisition, and to take place within the hours of nine and twelve at night, without performance of any of the rites of Christian burial.

The Code Pénal of France contains no legislation on the subject of suicide. Of the modern codes of Germany, some adopt the silence of the French code, and others vary in their particular provisions. In the Bavarian and Saxon codes suicide is not mentioned. The Prussian code forbids all mutilation of the dead body of a self-murderer under ordinary circumstances; but declares that it shall be buried without any marks of respect otherwise suitable to the rank of the deceased; and it directs that if any sentence has been pronounced, it shall, as far as it is feasible, be executed, due regard being had to decency and propriety, on the dead body. Besides which, the body of a criminal who commits self-murder to escape the execution of a sentence pronounced against him is to be buried at night by the common executioner, at the usual place of execution for criminals. The Austrian code simply provides that the body of a self-murderer shall be buried by the officers of justice, but not in a churchyard or other place of common interment.

SUIT is a legal term used in different senses. The word *secta*, which is the Latin form, is from "sequor," to follow; and hence the general meaning of the word may be deduced.

1. A suit is a proceeding by which any legal or equitable right is enforced in a court of justice. Where the remedy is sought in a court of law, the term is synonymous with action; when the proceeding is in equity, the term suit is alone used. It is also applied to proceedings in the ecclesiastical and admiralty courts.

2. Suit of court, in the sense of an obligation to follow, that is, to attend, and to assist in constituting a court, is either real or personal.

Suit-real, or rather suit regal, is the obligation under which all the residents within a leet or town are bound to attend the king's criminal court for the district, whether held before the king's officer and called the sheriff's tourn, or held before the grantees of leets or the officers of such grantees, and called courts-leet. [LEET.]

Suit-personal is an obligation to attend the civil courts of the lord under whom the suitor holds lands or tenements; as in manors [MANORS] where there are copyhold, that is, customary estates, the custom imposes upon the copyholder an obligation to attend the lord's customary court. In the case of freeholders attending as suitors the county court or the court-baron (as in the case of the ancient tenants per baroniam attending parliament), the suitors are the judges of the court, and the sheriff in the county court, the lord or steward in the court-baron, only presiding officers with no judicial authority. But in the criminal jurisdiction of the tourn and leet, the sheriff and the grantee of the leet, or his steward, are the judges; and the suitors act only a subordinate part.

3. Besides suit of court, secta ad curiam, there are other species of personal suit, which, like suit of court, are divisible into suit-service and suit-custom. Of these the most usual is suit of mill, secta ad molendinum, which is where, by tenure or by custom, the freehold or customary tenant is bound to grind his corn at the lord's mill.

SUIT AND SERVICE. [Suit.]

SULPH, or SULPHO. A prefix used in chemistry in naming a large number of substances containing the element sulphur. Most of these bodies will be found described under their respective names; but others will be found under the name to which the prefix is added, thus sulpholeic acid is described under Oleic Acid.

SULPHACETIC ACID $(C_4H_4S_2O_{10})$. An organic acid formed by the action of anhydrous sulphuric acid upon monohydrated acetic acid. It crystallises in very deliquescent needles. It is bibasic.

SULPHAMETHYLANE. [Methyl, *sulphamate of.*]

SULPHAMYLIC ACID. [Amyl.]

SULPHANILIC ACID $(C_{12}H_7NS_2O_6)$. An unimportant derivative of aniline.

SULPHANISOLIC ACID. A synonyme of methylsulphophenic acid. [Methyl; Phenylic Group.]

SULPHANISOLIDE. [Phenylic Group.]

SULPHATAMMON. [Sulphur.]

SULPHATES. [Sulphur, *Sulphuric Acid.*]

SULPHETHAMIC ACID $(C_{16}H_{23}NS_4O_{16})$. An ammoniacal derivative of sulphate of ethyl. In its most concentrated form it is a liquid. Ebullition decomposes it.

SULPHETHYLIC ACID. [Ethyl.]

SULPHETHYLOLIC ACID. Synonymous with ethylsulphurous acid. [Ethyl.]

SULPHIDES. [Sulphur.]

SULPHINDIGOTIC ACID. [Indigo.]

SULPHINDYLIC ACID. [Indigo.]

SULPHION. [Sulphur.]

SULPHISATANOUS ACID $(C_{16}H_{11}NO_4; S_2O_4)$. A crystalline acid of no importance derived from indigo.

SULPHISATHYD. [Indigo.]

SULPHITES. [Sulphur, *Sulphurous Acid.*]

SULPHOAMIDONIC ACID. [Sugar.]

SUPHOBENZIDIC ACID. [Phenyl-sulphurous Acid.]

SULPHOBENZIDE. [Phenylic Group.]

SULPHOBENZOENIC ACID. [Toluenic Group.]

SULPHOBENZOL $(C_{14}H_6S_2)$. A white crystalline organic substance isomeric with hydride of sulphobenzöyl. It is obtained by acting upon hydride of chlorobenzöyl with sulph-hydrate of potash.

SULPHOCARBONIC ACID. [Sulphur.]

SULPHOCARBONIC ETHER. [Ethyl.]

SULPHOCARBOMETHYLIC ACID. A synonyme of methyldisulphocarbonic acid. [Methyl.]

SULPHOCETIC ACID. [Cetyl, *Cetyl-sulphuric Acid.*]

SULPHOCHOLEIC ACID. [Choleic Acid.]

SULPHOCYANHYDRIC ETHER. [Ethyl.]

SULPHOCYANOGEN. [Cyanogen, *Cyanogen and Sulphur.*]

SULPHOFORM. [Methyl.]

SULPHOFLAVIC ACID. [Indigo.]

SULPHOFULVIC ACID. [Indigo.]

SULPHOFURETHANE. [Carbamic Acid.]

SULPHOGLUCIC ACID. [Sugar.]

SULPHOGLUTINIC ACID. [Naphthalic Group.]

SULPHOHAMATHIONIC ACID. An acid of problematical existence, said to be derived from Purree, or Indian Yellow.

SULPHOLIGNIC ACID. [Sugar.]

SULPHOMESITYLIC ACID $(C_{18}H_{12}S_2O_6)$. A crystalline acid produced by dissolving mesitylene in fuming sulphuric acid.

SULPHOMETHYLIC ACID. A synonyme of methyl-sulphuric acid. [Methyl.]

SULPHOMETHYLSULPHURIC ACID. A synonyme of methyl-sulphurous acid. [Methyl.]

SULPHOMOLYBDIC ACID. [Molybdenum, *sulphides of.*]

SULPHOMORPHIDE. [Opium, Alkaloids of.]

SULPHONAPHTHALIDAMIC ACID. [Naphthalic Group.]

SULPHONAPHTHALIDE $(C_{24}H_{10}SO_2?)$. A derivative of naphthalin is said to possess this formula, but it is probably a mixture of naphthalin and sulphonaphthalin.

SULPHONAPHTHALIN. [Naphthalic Group.]

SULPHONARCOTIDE. [Opium, Alkaloids of.]

SULPHOPHENIC ACID. [Phenylic Group.]

SULPHOPHENICIC ACID. [Indigo.]

SULPHOPHENYLAMIDE. [Phenylic Group.]

SULPHOPHENYLIC ACID. [Phenyl-sulphuric Acid.]

SULPHOPINIC ACID. [Opium, Alkaloids of.]

SULPHOPURPURIC ACID. [Indigo.]

SULPHORUFIC ACID. [Indigo; Salicylic Group.]

SULPHO-SALTS, or SULPHUR-SALTS. [Salts.]

SULPHOSINAPIC ACID $(C_8H_7NS_4)$. *Allyl-sulphocarbamic Acid.* An organic acid produced by the action of an alcoholic solution of potash upon sulphocyanide of allyl. The potash salt of the acid is thus obtained; the acid itself has not been isolated.

SULPHOSINAPISINE. [Sinapine.]

SULPHOTOLUENIC ACID. [Toluenic Group.]

SULPHOVINIC ACID. *Ethylsulphuric Acid* [Ethyl.]

SULPHOVIRIDIC ACID. [Indigo.]

SULPHOURETHANE. [Carbamic Acid.]

SULPHUR (S); commonly called *brimstone,* is a solid elementary non-metallic body, which has been known from the most remote antiquity. The former term is derived from *sal* salt, and *πῦρ* fire; the latter *brennestone* or *burnstone,* both in allusion to its well-known property of ready inflammability. It is met with in the pure state and in various forms of combination: thus it is found combined with numerous metals and in immense quantity with iron, forming the sulphide and bisulphide; with copper, lead, antimony, &c., constituting the principal ores of these metals: it is also found largely combined with oxygen, forming sulphuric acid, which is generally united with an earthy base, as with lime, constituting sulphate of lime, or gypsum; and with baryta, strontia, and magnesia, giving rise to the sulphates of those bases. It occurs also, but in smaller quantity,—and principally in mineral waters, such as those of Harrowgate,—combined with hydrogen, the compound being sulphuretted hydrogen gas, or hydrosulphuric acid. Sulphur is a constituent of some animal substances, as albumen, urine, &c. It is found also in certain plants: in the natural order *Liliaceæ,* as in garlic; *Cruciferæ,* as in mustard; and *Umbelliferæ,* as in *Asafœtida.*

The chief source of this element is *native sulphur,* the most remarkable deposits of which occur in Sicily, whence an immense quantity is imported into this country. It occurs also in the fissures of lava near the craters of volcanoes, in Italy, Guadaloupe, Nevis, Iceland, and the volcanoes of the Cordilleras. [Sulphur, in Nat. Hist. Div.]

Sulphur is separated from the grosser impurities by crude processes of fusion and distillation, performed soon after it is collected. That sent to Great Britain is, however, finally purified in this country, and has different forms given to it according to circumstances. What is called *refined sulphur* is that purified by distillation in a large cast-iron still, and condensed in a receiver kept cool. When the vaporised sulphur is condensed in a large chamber, it has the form of powder, and is called *sublimed sulphur* or *flowers of sulphur;* but as the walls of the chamber get hot, the sulphur melts, collects on the floor, and is run off into wooden moulds, the product being *roll* or *stick sulphur.* The residue in the retort still contains sulphur, and, under, the name of *sulphur vivum* or *black sulphur,* is occasionally used as a cattle medicine and for dressing mouldy hops.

Precipitated sulphur or *milk of sulphur,* is a finely divided form of the element thrown down on adding a strong solution of polysulphide of calcium, sodium, or potassium to dilute hydrochloric acid; sulphuric acid is sometimes used instead of hydrochloric, sulphate of lime being thereby precipitated along with the sulphur, and the weight of the latter thus fraudulently increased. This adulteration may readily be detected on heating a little of the suspected specimen, when the sulphur being volatile will be expelled, and the sulphate of lime left behind. The microscope also will at once detect the falsification, for the sulphur has a fine granular appearance, while the gypsum is in well defined crystals.

Sulphur is sometimes prepared from iron pyrites (FeS_2), by distillation. One third of the sulphur present in the ore is volatilised and condensed in the usual way, while magnetic pyrites (Fe_3S_4) remains in the retort. Sulphide of copper is also a source of sulphur, the latter being a sort of bye-product, although an important one, in the preliminary roasting operations connected with copper smelting.

Sulphur has already been referred to [Allotropy] as existing in three allotropic states. The first form ($S\alpha$) is that of an octohedral crystal with a rhombic base, and is the condition in which it occurs in nature. It is artificially obtained in the same form, but more transparent on allowing its solution in chloride of sulphur or bisulphide of carbon to evaporate spontaneously; its specific gravity is 2·05, and it fuses at 239° Fahr. The second form ($S\beta$) occurs in transparent acicular crystals of dark yellow colour. To obtain it, a quantity of sulphur is melted and slowly cooled; when the outer portions have solidified, holes are made in the crust, and the still liquid sulphur in the interior is poured out; on breaking open the shell its inner surface will be found to contain the needles in question. They are not permanent, but soon change into the light yellow semi-opaque sulphur (α); the acicular form is, however, still retained, although each needle is a congeries of minute rhombic octohedra. Much heat is evolved during the transformation. The third state ($S\gamma$) is very peculiar, and is brought about as follows:—The fusing-point of sulphur is 239°, and between this and 280° it possesses the highest degree of fluidity: at 320° it begins to thicken, and at 482° is so tenacious, that it will scarcely flow from an inverted vessel; from this to 600°, which is its boiling-point, it again becomes liquid, but not so perfectly so as at 280°. If now it be poured into water it becomes a brown pasty mass, which readily receives and retains any form given to it, and hence is employed in taking casts. Magnus has shown that this deepening in colour is due to a fourth modification of sulphur, which is black; it is formed on many times repeating the process of heating a quantity of sulphur to 600° Fahr., and suddenly cooling in cold water.

Sulphur is insoluble in water, but dissolves in alcohol, if both substances are exposed to each other in the state of vapour: on the addition of water, the sulphur is precipitated. It is dissolved by boiling oil of turpentine; the solution has a reddish-brown colour, and, on cooling, minute crystals of sulphur are deposited. It is readily taken up by chloride of sulphur, and is soluble in about three times its weight of bisulphide of carbon; the elastic variety is, however, not so soluble. Sulphur is also soluble to a small extent in ether and in chloroform.

Sulphur is a bad conductor of heat; it is very volatile, and when it is rubbed in the dark on a brick, or any other substance by which it is heated, though not sufficiently to inflame it, an extremely weak blue flame arises, exhaling a peculiar odour; this flame is not, however, occasioned by combustion, it merely accompanies the evaporation of the sulphur, for a cold body held over it is covered with flowers of sulphur. When sulphur is heated, it begins to vaporise before it fuses; at 600° Fahr. it is rapidly volatilised, and in close vessels is condensed without change. The specific gravity of the vapour of sulphur is 6·617 at 900° Fahr., but at 1900° Fahr. it is 2·2. Its combining volume below 1500° Fahr. is ⅓, but at 1900° Fahr. it is 1. It unites directly with some metals to form *sulphides*.

When heated in the air sulphur quickly takes fire and burns with a pale blue flame, generating much heat.

The equivalent of sulphur is 16.

Compounds of Sulphur and Oxygen are seven in number, namely :—

		Sulphur per cent.	Oxygen per cent.
Sulphurous acid . . .	SO_2	50·00	50·00
Sulphuric acid	SO_3	40·00	60·00
Hyposulphurous acid . .	S_2O_2	66·66	33·34
Hyposulphuric acid . . .	S_2O_5	44·45	55·55
Trithionic acid . . .	S_3O_5	54·55	45·45
Tetrathionic acid . . .	S_4O_5	61·53	38·47
Pentathionic acid . . .	S_5O_5	66·66	33·34

Sulphurous acid (SO_2) *Sulphurous anhydride.*—This gas escapes, in the gaseous state, from fissures in the ground in the neighbourhood of volcanoes. It is artificially obtained in the pure state on heating about two parts of mercury with three of strong sulphuric acid :—

$$\underbrace{Hg}_{\text{Mercury.}} + \underbrace{4(HO, SO_3)}_{\text{Sulphuric acid.}} = \underbrace{HgO_2, 2SO_3}_{\text{Bisulphate of mercury.}} + \underbrace{4HO}_{\text{Water.}} + \underbrace{2SO_2}_{\text{Sulphurous acid.}}$$

Copper clippings may be economically substituted for mercury, but as met with in commerce they generally contain matters that affect the purity of the gas. On the large scale, solution of sulphurous acid is preferable to the gas itself, and is manufactured directly from sulphur. The latter is burnt in a furnace, and the sulphurous acid produced cooled by passing through earthenware tubes surrounded by cold water. It is then made to ascend through a tall and wide wooden column packed with pumice-stone that has been digested in hydrochloric acid and well washed. In ascending the sulphurous acid meets with a stream of water, the flow of which is so regulated that a saturated solution shall flow off at the bottom of the column. It is stored for use in a closed reservoir.

Sulphurous acid gas is colourless, and permanently elastic; that is, not condensed into a fluid or solid by exposure to common degrees of cold under the ordinary pressure. It condenses to the liquid state, however, on being passed through a tube surrounded by a freezing mixture of ice and salt. In this condition it may be preserved in hermetically sealed tubes, on the interior of which, at 60° Fahr., it exerts a pressure of two and a half atmospheres. At —105° Fahr. it freezes to a colourless, transparent, crystalline solid.

Sulphurous acid gas has a pungent and suffocating odour, being that experienced whenever sulphur is burned; its taste is disagreeable and acid; it extinguishes burning bodies, is not inflammable, and is fatal to animals. Water at 60° Fahr. dissolves from 33 to 37 times its volume of this gas; by heating the solution it is evolved unaltered. The solution possesses the smell of the gas itself; and, like it, has the property of bleaching some vegetable and animal substances: hence the employment of the vapour of burning sulphur in whitening hops, silk, wool, and straw.

One hundred cubic inches of sulphurous acid gas weigh 68·8 grains; its density therefore is about 2·22. Being so much heavier than air it may be collected in vessels by displacement. [Gases, Collection of.]

The aqueous solution of sulphurous acid, when exposed to oxygen, slowly combines with it, and the result is sulphuric acid; but unless moisture be present, no combination takes place between these two gases.

Sulphurous acid combines with various bases to form salts, which are called *sulphites*. When, for example, this gas is passed into an aqueous solution of ammonia, they readily combine, and the resulting salt is sulphite of ammonia, which may be obtained in prismatic crystals. It is very soluble in water, and produces much cold during solution; by exposure to the air it attracts oxygen, and becomes sulphate of ammonia. When, however, dry sulphurous acid gas and dry ammoniacal gas are brought into contact, deep yellow-coloured crystals are formed, which have been termed *sulphitammon*, or improperly *sulfamide;* they contain the elements of sulphurous acid and ammonia combined, but in a different mode to that which forms anhydrous sulphite of ammonia. By exposure to the air sulfamide becomes white, deliquesces, and gradually becomes sulphate and hyposulphate of ammonia.

The alkalies potash and soda, the alkaline earths, and several metallic oxides, may be combined with sulphurous acid, and they form *sulphites;* but these compounds are not of much importance, except perhaps that of soda. [Sodium, *sulphite of.*] In contact with air they are slowly converted into sulphates.

Sulphuric Acid (HO, SO_3).—This acid has been long known, and is very extensively employed, 100,000 tons being annually consumed in Great Britain alone. When combined with water, in which state it is best known, it was originally, and still is frequently, called *oil of vitriol:* first, because it is an oily looking liquid; and secondly, on account of its being obtained from green vitriol, or copperas, now called sulphate of iron.

The process just alluded to was first followed at Nordhausen in Germany, and the peculiar compound of sulphuric acid and water produced by it is still called Nordhausen oil of vitriol, to distinguish it from common oil of vitriol, a different compound as regards the water which they contain, and obtained by a different process. We shall first describe the original process and product.

Iron pyrites is a well known and very abundant natural substance: it is correctly termed *bisulphide* of iron, and consists of two equivalents of sulphur and one equivalent of iron. When certain varieties of this compound are exposed to air and moisture, both the sulphur and iron are oxidised at the expense of the oxygen of the air; and though sulphur by itself is incapable of undergoing this change, yet, when combined with iron, it acquires from the air sufficient oxygen to become sulphuric acid, and the iron attracts enough to become protoxide; and these combining together, and with water, constitute the well-known crystalline body, hydrated sulphate of protoxide of iron, usually called, for brevity's sake, merely sulphate of iron, and originally green vitriol. This consists of one equivalent of sulphuric acid, one of protoxide of iron, and seven equivalents of water. Sulphuric acid consists of three equivalents of oxygen and one equivalent of sulphur. In order to procure the acid from it, the salt is moderately heated, so as to expel the greater part of the water: in this state it is put into earthen retorts, and subjected to a very high temperature, during which there comes over and condenses in the receiver a dark-coloured dense fluid, which is the Nordhausen oil of vitriol; the cause of the colour has not been ascertained, but it appears to be an accidental and not a necessary accompaniment. This liquid emits a white vapour when exposed to the air, and hence it is called *fuming sulphuric acid.* It is composed of two equivalents of sulphuric acid and one equivalent of water ($HO, 2SO_3$).

Now it happens that anhydrous sulphuric acid is more volatile than that combined with water, so that when the above acid is heated in a retort, there first comes over and condenses in the receiver anhydrous sulphuric acid, and there remains in the retort hydrated sulphuric acid.

We shall first and briefly state the properties of the anhydrous acid. It is a colourless crystalline solid, is tough and elastic, liquefies at 66°, and boils at a temperature between 104° and 122°, forming a transparent vapour, provided no water is present; it unites with moisture when exposed to the air, and forms with it dense white fumes. It is sometimes prepared as a matter of curiosity, but is hardly applied to any use. Though called an acid, it in reality possesses no acid properties, and may be moulded in the fingers, like wax, without injuring the skin. When thrown into water it hisses as red-hot iron would do, and then has the usual powerful properties of common hydrated sulphuric acid.

The hydrated sulphuric acid, commonly called oil of vitriol, or simply sulphuric acid, is the compound which is so largely employed in numerous chemical operations and manufactures. It is, however, and has indeed for many years been, prepared in a much preferable mode to that described by the decomposition of sulphate of iron. The process consists in oxidising sulphurous acid through the agency of nitrous acid.

First, nitrate of potash or soda is decomposed by the addition of sulphuric acid, in the same mode as that employed for preparing nitric acid.

Sulphur is then burned in a furnace so contrived that the current of air which supports the combustion conducts the gaseous products, including the nitric acid fumes and excess of air, into large leaden chambers, the bottoms of which are covered to the depth of a few inches with water. The nitric acid of the nitre, composed of oxygen and nitrogen, is here decomposed, yields oxygen to a portion of the sulphurous acid formed by combustion, and converts it into sulphuric acid. The nitric acid, on losing oxygen, is converted into nitric oxide, which, by mixing with the air at the moment of its separation, combines with its oxygen, and gives rise to red nitrous acid vapour. The gaseous substances present in the leaden chambers are therefore sulphurous and nitrous acids, atmospheric air, and watery vapour. Now, when dry sulphurous acid gas and dry nitrous acid gas are mixed together, no action occurs between them; but when a little moisture is added, a white crystalline compound of sulphuric acid, hyponitrous acid, and water is formed; and when this falls into the water of the chamber, or comes into contact with steam, which is for this purpose blown into the chamber, it is instantly decomposed, the sulphuric acid is dissolved, and nitrous acid and nitric oxide gases escape with effervescence. The nitrous acid thus set free, as well as that reproduced by the nitric oxide uniting with the oxygen of the atmosphere, is again intermixed with sulphurous acid and moisture, and thus gives rise to a second portion of the crystalline body, which undergoes the same change as the first; and this operation is repeated until the water at the bottom of the lead-chambers is sufficiently acid to be removed for ulterior operations. The amount of nitric acid required in this operation is of course exceedingly small, inasmuch as the nitric oxide contained in it is not consumed, but acts only as a carrier of oxygen from the air to the sulphurous acid. Some nitric oxide is, however, conveyed out of the chambers by the escaping nitrogen of the air, and is in most works lost. A few manufacturers cause the escaping gases to pass over strong sulphuric acid that is trickling through a coke column, by which the nitric oxide is dissolved and subsequently recovered from the liquid by exposure to a stream of sulphurous acid in a second similar coke column.

It thus appears that sulphur during combustion can combine only with sufficient oxygen to become sulphurous acid; but what is curious is, that sulphurous acid becomes sulphuric acid by taking oxygen from nitrous acid, the nitric oxide of which appears nevertheless to have a stronger affinity for oxygen, since it can take that element rapidly from the air, which sulphurous acid cannot. The first attempt at explaining the mode in which nitric acid acts in this operation was made by MM. Clement and Desormes: it was subsequently further explained by Davy and other chemists.

Of late years also sulphuric acid has been made from iron pyrites, the sulphurous acid being formed by combustion, and converted into sulphuric by the agency of nitrous acid, in the manner already described.

When the sulphuric acid in the chambers has acquired a density of about 1·6, it is drawn off and further concentrated in open leaden vessels by heat; after this it is again removed either to glass or platina retorts, and heated till it has acquired a density of about 1·846. This is then the sulphuric acid, or oil of vitriol, of commerce, composed of one equivalent of sulphuric acid and one equivalent of water (HO, SO_3).

This acid is a limpid, inodorous, colourless fluid, of an oily consistence. It boils at about 620°, and distils over unchanged; the boiling-point diminishes with dilution: thus, when of specific gravity 1·78 it boils at 435°, and when 1·65 only at 350°, the concentrated acid freezes at −15°, but when it contains two equivalents of water instead of only one, and has a specific gravity of 1·78, it freezes at −40°.

Sulphuric acid is intensely caustic and acrid, and readily decomposes animal and vegetable fibre; even when diluted to a very great extent it has an extremely sour taste, and turns vegetable blues strongly red: on the other hand, when concentrated, it turns turmeric-paper of a brownish colour, as the alkalies do; but the effect is not permanent, for it is removed by water. Its affinity for water is very great, attracting it so readily from the air that in moist weather three parts increase to four in 24 hours, and by longer exposure the quantity is increased. When suddenly mixed with water, much heat is evolved, and, on cooling, condensation is found to have taken place, the two fluids occupying less space than before mixture. When sulphuric acid is mixed in certain proportions with snow, heat is given out, or cold generated, according to the quantities employed: thus four parts of acid and one of snow evolve heat, but four of snow and one of acid occasion cold.

Sulphuric acid is employed for a vast number of purposes: thus, on account of its great chemical power, it is used for the purpose of separating other acids from bases, as in preparing nitric, hydrochloric, acetic, phosphoric, and carbonic acids, &c. It is also used in preparing sulphates, a class of salts we shall presently again refer to. Perhaps the greatest consumption of sulphuric acid is in the decomposition of salt at alkali works where carbonate of soda is manufactured.

The strength of sulphuric acid is readily ascertained by taking its specific gravity and referring to such a table as the following, constructed by Ure:—

Specific gravity.	SO_3 in 100 parts.	Percentage of HO, SO_3.	Specific gravity.	SO_3 in 100 parts.	Percentage of HO, SO_3.
1·8460	81·54	100	1·6415	60·34	74
1·8415	79·90	98	1·6204	58·71	72
1·8366	78·28	96	1·5975	57·08	70
1·8288	76·65	94	1·5760	55·45	68
1·8181	75·02	92	1·5503	53·82	66
1·8070	73·39	90	1·5280	52·18	64
1·7901	71·75	88	1·5066	50·55	62
1·7728	70·12	86	1·4860	48·92	60
1·7540	68·49	84	1·4660	47·29	58
1·7315	66·86	82	1·4460	45·66	56
1·7080	65·23	80	1·4265	44·03	54
1·6860	63·60	78	1·4073	42·40	52
1·6624	61·97	76	1·3884	40·77	50
1·3697	39·14	48	1·1549	17·94	22
1·3530	37·51	46	1·1410	16·31	20
1·3345	35·88	44	1·1246	14·68	18
1·3165	34·25	42	1·1090	13·05	16
1·2999	32·61	40	1·0953	11·41	14
1·2826	30·98	38	1·0809	9·78	12
1·2654	29·35	36	1·0682	8·15	10
1·2490	27·72	34	1·0544	6·52	8
1·2334	26·09	32	1·0405	4·89	6
1·2184	24·46	30	1·0268	3·26	4
1·2032	22·83	28	1·0140	1·63	2
1·1876	21·20	26	1·0074	0·815	1
1·1706	19·57	24			

The salts which sulphuric acid forms with various bases are termed *sulphates*, *sesqui-sulphates*, or *bi-sulphates*, &c., according to circumstances. They are a very important class of saline bodies, and those of most use will be found described under their respective bases. With sulphuric anhydride, dry ammoniacal gas forms large transparent crystals, containing NH_3, SO_3, and termed *sulphatammon;* by long boiling with water, it is converted into sulphate of ammonia (NH_4O, SO_3).

According to the binary theory of the constitution of salts, sulphates are not combinations of the basic oxide and sulphuric acid, but of a hypothetical body, *sulphion* (SO_4), with the metal, or radical, of the base: thus, sulphate of soda (NaO, SO_3) is *sulphionide of sodium* (Na, SO_4), and sulphuric acid (H, SO_4) *sulphionide of hydrogen.* There are, however, several objections to this view of the constitution of sulphates.

Sulphuric acid in its concentrated state, and at common temperatures, acts only slightly, if at all, on the metals; but when they are heated together, the acid is generally decomposed, sulphurous acid and a sulphate of metallic oxide being produced: thus, when copper is heated in concentrated sulphuric acid, the acid yields one of its three equivalents of oxygen to the copper, which becomes protoxide; while the sulphur combined with two equivalents of oxygen is given off in the state of sulphurous acid; and this, as already indicated, is one of the best methods of procuring sulphurous acid. When, on the other hand, sulphuric acid is diluted, it has no action, even when heated, on copper; but on zinc, iron, and such other metals as readily decompose water, it acts with great readiness: the metal, being oxidised by the oxygen of the decomposed water, is dissolved by the acid, while the hydrogen of the water is given out in the gaseous state; by this operation, then, we procure a metallic sulphate and hydrogen gas.

Sulphuric acid and all sulphates are decomposed by the salts of baryta and of lead, minute quantities either of the acid or soluble salts being rendered evident by the formation of a dense white precipitate either of sulphate of baryta or lead; 116·5 parts of the former or 115·6 parts of the latter sulphate, when dry, indicate 40 parts of anhydrous sulphuric acid.

Commercial sulphuric acid generally contains sulphate of lead derived from the vessels used in its manufacture; it is nearly all precipitated as a white powder on diluting the acid with water. It frequently also contains traces of arsenic derived from the pyrites; in this case, sulphuretted hydrogen gives a yellow precipitate when passed through the diluted acid, or the contamination may be detected by Marsh's test. Small quantities of nitric and sulphurous acids are also sometimes present in common sulphuric acid. If required to be purified and concentrated, it is boiled and distilled. As lead would melt at the heat here employed, and as most other common substances would be corroded, platinum is often employed as a material for the still, at a heavy expense. Glass is another material employed for sulphuric acid stills. When the acid has been condensed to a specific gravity nearly double that of water, it is ready for sale.

Hyposulphurous Acid (HO, S_2O_2). *Dithionous acid.* In 1817 Dr. Thomson inferred the existence of an acid of sulphur in the salts called *sulphuretted sulphites:* this acid and its compounds have been particularly examined by Sir John Herschel.

Hyposulphurous acid has not been obtained in a separate state, but its composition has been determined to be in accordance with the above formula.

This acid is procured by dissolving zinc or iron in close vessels in an aqueous solution of sulphurous acid: solution is effected in this acid without the evolution of any gas, which hardly happens in any other case: the metals thus dissolved form crystallisable salts, which, when decomposed by other acids, yield sulphurous acid and sulphur, previously existing in the proportions above stated, and constituting hyposulphurous acid: this acid is also formed when sulphites are digested in close vessels with sulphur, in which case the sulphur takes half the oxygen of the sulphurous acid; when iron is dissolved in sulphurous acid, it takes half the oxygen of the sulphurous acid, which, by this loss becomes hyposulphurous acid, and, combining with the oxide of iron formed, they constitute hyposulphite of iron.

Most of the salts containing hyposulphurous acid, or the hyposulphites, are unimportant; the acid undergoes decomposition when they are strongly heated or acted upon by an acid.

Hyposulphite of soda ($NaO, S_2O_2 + 5$ Aq.), in solution, is largely used in photography to "fix," or render permanently unalterable the photographic picture. This it does by dissolving the aqueously insoluble silver salts, with which it forms double compounds having an intensely sweet taste. Hyposulphite of soda is made by dissolving sulphur in sulphite of soda, $NaO, SO_2 + S$ becoming NaO, S_2O_2.

Hyposulphuric Acid (HOS_2O_5). *Dithionic Acid.* This acid was discovered in 1819 by Gay-Lussac and Welter. It is prepared by suspending finely-powdered binoxide of manganese in water, and passing sulphurous acid gas into the mixture: if this be not kept cold, sulphuric acid is formed: but otherwise the oxide of manganese is dissolved and hyposulphate of its protoxide formed: to the filtered solution sulphide of barium is to be added, by which sulphide of manganese is precipitated, and hyposulphate of baryta remains in solution: when the proper quantity of sulphuric acid is added to this, sulphate of baryta is precipitated, and the hyposulphuric acid is liberated, the filtered solution of which is to be evaporated in vacuo over sulphuric acid till it acquires a density of 1·347: if it be carried further than this, it is decomposed into sulphurous acid, which escapes, and sulphuric acid, which remains dissolved.

This acid has not been obtained free from water: the aqueous solution is sour, inodorous, and reddens vegetable blues: if heated to 212°, it is decomposed into sulphurous and sulphuric acids; and when exposed to the air, it slowly absorbs oxygen; and becomes sulphuric acid. Unlike sulphuric acid, it forms soluble compounds with lime, baryta, strontia, and oxide of lead; but, like diluted sulphuric acid, it acts upon and dissolves zinc, with the evolution of hydrogen gas, and a solution of hyposulphate of zinc is formed; its salts are decomposed at a high temperature, yielding sulphurous acid and sulphates remaining.

Trithionic acid (HO, S_3O_5). *Sulphuretted hyposulphuric acid.* As a potash salt this acid is formed when sulphur is digested in bisulphite of potash for several days, or until all yellow colour has disappeared. The resulting solution gives a black precipitate with subnitrate, and a white with pernitrate of mercury. From the trithionate of potash the acid may be liberated by tartaric acid, and obtained in unstable prismatic crystals by evaporation. By heat the trithionates split up into sulphur, sulphurous acid, and sulphate of the base.

Tetrathionic acid (HO, S_4O_5). *Bisulphuretted hyposulphuric acid.* Two equivalents of hyposulphite of baryta and one of iodine yield iodide of barium and tetrathionate of baryta. The latter may be purified by recrystallisation, and the acid liberated by the cautious addition of sulphuric acid. It is somewhat unstable.

Pentathionic acid (HO, S_5O_5). *Trisulphuretted hyposulphuric acid.* When sulphurous and hydrosulphuric acids come into contact, the following decomposition occurs:—

$$\underbrace{5SO_2}_{\text{Sulphurous acid.}} + \underbrace{5HS}_{\text{Hydrosulphuric acid.}} = \underbrace{HO, S_5O_5}_{\text{Pentathionic acid.}} + \underbrace{S_5}_{\text{Sulphur.}} + \underbrace{4HO}_{\text{Water.}}$$

Pentathionic acid is very unstable. Its baryta compound may be obtained in silky scales.

Chlorosulphuric acid or *chloride of sulphuryl* (SO_2Cl). A colourless liquid of pungent odour and powerful eye-irritating properties, formed on bringing together dry sulphurous acid and chlorine gases in bright sunlight. It is volatile without decomposition, but water instantly breaks it up. It does not appear to combine with bases.

Nitrosulphuric acid (HO, SO_2NO_2). If nitric oxide (NO_2) be passed through a cold solution of sulphite of ammonia containing large excess of ammonia, white crystals of *nitrosulphate of ammonia* (NH_4O, SO_2NO_2) are deposited. Other nitrosulphates may be formed, but they are very unstable, and the acid cannot be liberated from them.

Sulphazotised acids, discovered by Fremy, form with potash, but not with soda, a remarkable series of salts. They are derived from basic nitrite of potash, sulphurous acid and water, as indicated in the following equations:—

Sulphazite of potash . . . . $3KO, S_3NH_3O_{12}$
from $3KO, NO_3 + 3SO_2 + 3HO$.
Sulphazate of potash . . . . . $3KO, S_4NH_3O_{14}$
from $3KO, NO_3 + 4SO_2 + 3HO$.
Sulphazotate of potash . . . . $3KO, S_5NH_3O_{16}$
from $3KO, NO_3 + 5SO_2 + 3HO$.
Sulphammonate of potash . . . . $4KO, S_8NH_3O_{22}$
from $4KO, NO_3 + 8SO_2 + 3HO$.

Nitrogen and Sulphur. [NITROGEN.]

Hydrogen and Sulphur combine in two proportions, forming *hydrosulphuric acid* (HS), frequently called *sulphuretted hydrogen*, and persulphide of hydrogen (HS_2 ?).

Hydrosulphuric acid, formerly known by the name of hepatic gas, exists in sulphurous waters, such as those of Harrowgate. It may be formed, to a certain extent, by heating or subliming sulphur in hydrogen gas. It is usually produced by the action of hydrochloric acid on sulphide of antimony, or by acting upon protosulphide of iron with dilute sulphuric acid: in the former case the hydrogen of the hydrochloric acid unites with the sulphur of the sulphide, chloride of antimony being also formed; while in the latter, the decomposed water yields hydrogen to the sulphur and oxygen to the iron, which latter, being then dissolved by the acid, constitutes sulphate of iron. As it is difficult to combine the whole of any given quantity of iron with sulphur, the uncombined portion yields a little free hydrogen with the hydrosulphuric acid; but this, in most cases, is of no consequence. Although hydrosulphuric acid is soluble in one-fourth its bulk of water, yet the gas may for most purposes be received by displacement in vessels filled with that liquid.

Hydrosulphuric acid is colourless, and gaseous at common temperatures and pressures: it has a peculiarly nauseous and fetid odour, resembling that of putrid eggs; its taste is also extremely disagreeable. Its specific gravity is about 1·192. 100 cubic inches weigh about 38 grains. It is composed of one equivalent of hydrogen and one equivalent of sulphur, as indicated in the above formula. It reddens moist litmus-paper, but not strongly, and is soluble in about one-third of its bulk of water. At a temperature of 50°, and under a pressure of about 17 atmospheres, it is rendered a limpid liquid, of specific gravity about 0·9: this does not congeal till cooled down to 122° Fahr. It is extremely poisonous to animals: air containing 1-1500th of its bulk immediately killed a bird, and 1-1000th a middle-sized dog. When mixed and detonated with oxygen gas, the results are water and sulphurous acid.

The aqueous solution of hydrosulphuric acid is employed as a test of metals, and, more especially, for the discovery of minute portions of lead, with which it gives a dark-coloured precipitate of sulphide of lead: with the salts of antimony it gives an orange precipitate, and with arsenious acid a yellow one.

Hydrosulphuric acid forms salts which are termed *hydrosulphates*, and these are probably formed when it is combined with ammonia, potash, soda, and the alkaline earths; but by metallic oxides, properly so called, it is decomposed, the results not being hydrosulphates of metallic oxides, but water and a metallic sulphide: this is the case with oxide of lead, silver, &c.

Persulphide of Hydrogen (HS_5 ?). This compound cannot be formed by direct combination. To prepare it, equal weights of sulphur and recently slaked lime may be boiled in three times their weight of water for half an hour. The result is a deep reddish-yellow coloured solution of persulphide of calcium, which, when clear and cold, is to be added to an excess of hydrochloric acid diluted with about twice its weight of water: by their mutual action sulphur is precipitated, accompanied by a yellow oil-like fluid, which is the persulphide of hydrogen. It is a viscid liquid, of a yellow colour, and of specific gravity about 1·77; its smell is similar to, but not so powerful as that of hydrosulphuric acid; its elements are held together by a feeble affinity, so that even in the cold it is gradually converted into hydrosulphuric acid and sulphur, and this change is immediately produced at 212°.

Chlorine and Sulphur appear to form two compounds, the chloride and di-chloride. According to Dumas, when sulphur is acted upon by excess of chlorine, a *neutral chloride* is obtained, which consists of one equivalent of chlorine and one equivalent of sulphur (SCl).

It usually contains some di-chloride, from which it is to be purified by repeated distillation at about 140° Fahr.

It may be formed either by heating sulphur in excess of dry chlorine gas, or, at common temperatures, by passing excess of chlorine through a tube containing powdered sulphur.

Chloride of sulphur is liquid, has a reddish-brown tint, and a density of 1·62; that of its vapour being about 3·7. Its boiling-point is 147°.

Di-chloride of Sulphur (S_2Cl).—This substance was first obtained by Dr. Thomson. When chlorine gas is passed over powdered sulphur, gently heated, it gradually disappears, and the di-chloride is formed by direct combination: the liquor obtained is to be distilled, and then possesses the following properties:—It is liquid, and is red by reflected, and yellowish-green by transmitted light: it emits acrid fumes when exposed to the air; its density is 1·628, that of its vapour being 4·7; it is volatile below 200°, and boils at 280°. Dry litmus-paper is not altered by it. It is energetically decomposed by and decomposes water, the results being hydrochloric and hyposulphurous acids. It does not combine with alkalies.

Sulphur and Bromine. [BROMINE.]

Carbon and Sulphur.—These form by direct action *bi-sulphide of carbon* (CS_2) or *sulphocarbonic acid.*

It may be obtained either by passing the vapour of sulphur over charcoal heated to redness in a porcelain tube, or distilling a mixture of bi-sulphide of iron and one-sixth of its weight of charcoal. It may be condensed by being passed into cold water, and to free it from uncombined sulphur and moisture it should be rectified from chloride of calcium at a low temperature.

It is a colourless transparent liquid, of density 1·272, that of its vapour being 2·447; it has an acrid pungent taste, and a very fetid odour; its refractive power is very high; it is insoluble in water, but combines with alcohol and ether, from which water precipitates it; it is extremely volatile, boils at 118·5°, and is not rendered solid at the lowest obtainable temperature: owing to its great volatility, it produces sufficient cold under the exhausted receiver of the air-pump to freeze mercury: it is extremely inflammable, the results of its combustion being carbonic and sulphurous acid gases, attended with a brilliant greenish-white flame. It combines with metallic sulphides to form a class of sulphur salts termed *sulpho-carbonates;* for example, sulpho-carbonate of potassium (KS, CS_2).

It is a remarkable circumstance that so volatile a liquid should be produced by the combination of two solid bodies. It was discovered by Lampadius in 1796.

Phosphorus and Sulphur. [PHOSPHORUS.]

Iodine and Sulphur. [IODINE.]

Selenium and Sulphur. [SELENIUM.]

Boron and Sulphur. [BORON.]

Sulphur Salts.—These are certain double sulphides, so designated by Berzelius: the electro-negative sulphides constituting *sulphur acids;* and the electro-positive sulphides, *sulphur bases.* Among the sulphur acids are the sulphides of arsenic, antimony, tellurium, tin, &c.; and in this class are also included sulphuretted hydrogen, bisulphide of carbon, and selenium and sulphocyanogen: the sulphur bases include the protosulphides of the metals of the alkalies and alkaline earths.

Compounds formed by the union of sulphur acids with sulphur bases are the *sulphur salts.*

The close chemical analogy between sulphur and oxygen is further seen on considering the constitution and properties of the following compounds of the two elements.

CO_2	CS_2	KO, AsO_3	KS, AsS_3
KO	KS	KO, AsO_5	KS, AsS_5
KO, CO_2	KS, CS_2	FeO	FeS
AsO_3	AsS_3	Fe_2O_3	Fe_2S_3
AsO_5	AsS_5	F_3O_4 (magnetic)	Fe_3S_4 (magnetic)

SULPHUR (in medicine) is an elementary principle which occurs in great abundance in the mineral, sparingly in the vegetable, and still more sparingly in the animal kingdom. In the vicinity of volcanoes sulphurous fumes issue copiously from the ground, and many mineral waters owe their peculiar odours and much of their virtues to sulphurous impregnations. Plants which contain it have often an offensive smell, to which most probably it contributes, constituting the *allyl* oils, such as asafœtida, garlic, and mustard, in which last it occurs as a constituent of myronic acid, a portion of which probably attaches to the volatile oil of mustard, the odour of which is stronger and more offensive than that of garlic and asafœtida combined. In animals it occurs in conjunction with albumen, and hence white of egg blackens silver egg-spoons.

For medical purposes, it should be as pure as possible, but in the two forms in which it occurs it is seldom perfectly free from admixture. Sublimed sulphur (flowers of sulphur) generally contains some sulphurous acid, which renders it slightly pungent; and precipitated sulphur, or milk of sulphur, mostly contains sulphate of lime. Of the two forms, precipitated sulphur, owing to the extremely fine state of subdivision in which it exists, is in equal quantities more powerful than the sublimed when freed from the large portion of sulphate of lime.

Sulphur is insoluble in water, very sparingly in alcohol, but soluble in oils, both fixed, such as linseed, and volatile, such as turpentine; with the former of which it forms the *balsamum sulphuris simplex,* with the latter the *balsamum sulphuris terebinthinatum.*

Though devoid of any marked sensible qualities, sulphur acts as a stimulant to the living tissues. Applied to the sound skin, it seems to have no effect upon it, but placed in contact with an ulcerated surface, it irritates and excites an inflammatory action. Large doses, such as a pound, given to horses, prove fatal by producing violent inflammation, recognisable during life by the symptoms, and after death by the morbid appearances. These may not have been due entirely to the sulphur, but to the tersulphide of arsenic (orpiment) with which sulphur is often contaminated. Hence the increased redness and sensibility of parts affected with cutaneous eruptions when sulphur is applied to them. It is clear therefore that it is by exciting to new action the unhealthy structures that it effects a cure of these diseases, and not by causing a repulsion or transfer of it to some other quarter, though this not unfrequently follows the too rapid healing of such complaints, if they have been spread over a large surface. Taken internally, sulphur gives rise to two distinct orders of effect: the one, its action on the intestinal canal; the other, upon the system generally. Small doses, if they do not increase the digestive power, at least do not disturb it; but larger cause a disagreeable sensation in the epigastric region, followed by alvine dejections, which are generally gentle, and without colic or griping. When it causes alvine evacuations, it does not produce marked general effects; but when given in small doses, with a sufficient interval between each to favour its absorption, its general action is commonly very apparent. The pulse becomes more frequent, the animal heat and perspiration are increased, and the presence of sulphur may be recognised in all the excretions of the body, or a transudation of it in the form of hydrosulphuric acid (sulphuretted hydrogen). In this way silver worn in the pocket of a person using sulphur becomes blackened.

The long-continued use of it gives rise to still more obvious stimulant effects. General excitement of the system takes place, increased arterial action leads to hæmorrhages, &c., accompanied by restlessness, sleeplessness, and thirst. The appearance of these symptoms should point out the propriety of suspending its further use till they can be removed by antiphlogistic means.

Sulphur should not be used for very plethoric individuals, or those inclined to high vascular action, till those states have been lessened by diet and other means.

Internally sulphur has been given in chronic catarrhs and humid coughs, as well as in some of the forms of asthma. From the power which sulphur undoubtedly possesses over mucous membranes, especially the bronchial, it is often serviceable; but in the asthmatic affections complicated with organic disease of the heart or great vessels, nothing can be more hurtful.

In chronic rheumatism sulphur, from its diaphoretic properties, is of much utility either alone or with antimonials. In those forms of dysentery which may be regarded as rheumatism of the intestines, sulphur is perhaps the best aperient in combination with ipecacuanha. It is also beneficial in those forms of paralysis which have resulted from rheumatism. It is stated to effect a cure of intermittents, and considering its power of rousing the vascular system, and its subsequent diaphoretic action, it may be used in those cases where arsenic fails and quinine is too expensive.

Sulphur is given as a laxative in hæmorrhoids, stricture of the rectum, and habitual constipation. For these cases it is usually combined with bi-tartrate of potash, or magnesia, or electuary of senna. A small quantity of the compound cinnamon-powder, or aromatic confection, is a valuable addition, as it lessens any tendency to griping, and also restrains the disposition to the disengagement of sulphuretted hydrogen gas, which is often a distressing consequence of the use of sulphur. The dose varies much in different individuals, but in all cases it should be ample, as an inefficient quantity is most prone to generate flatus. Persons of a sedentary habit, afflicted with constipation, find this combination of unspeakable service, as, unlike many others, it is not followed by greater constipation than before, but keeps the bowels moderately open for a considerable time. It is one of the most appropriate medicines for children or pregnant females.

Sulphur is generally given internally at the same time that it is used externally for the cure of cutaneous diseases. For one of these (*scabies*) it is regarded as almost a specific. Sulphur ointment is the form generally employed for this disease. It should never be applied to more than a fourth part of the body at one time. The compound sulphur ointment is more powerful, but requires still more caution in its employment from the veretrine it contains. In workhouse practice, the preferable mode of employing sulphur is by uniting it with soft-soap, which not only does not stain and grease the clothes, but assists in cleansing them as well as the patients when washed. Besides, the potash of the soap aids the cure. Many cutaneous diseases are more readily cured by a combination of sulphur with potash than by either singly. This combination, called *Potassii sulphuretum,* or liver of sulphur, may be applied in various ways, particularly in baths, forming artificial Harrowgate-water. The natural waters of Harrowgate, Moffat, and other sulphurous springs, owe their peculiarities to it.

Sulphur in combination with iodine, forming iodide of sulphur, when made into an ointment with a large quantity of lard or cerate, is a valuable agent in some cutaneous diseases. Sulphur sprinkled over the leaves of the vine is almost a certain preventive of the *oidium Tuckeri* or vine scourge. It is useful also for hops. See 'Gardeners' Chronicle,' March 30, 1861, p. 293, nor is it powerless against the potato disease. See 'Gardeners' Chronicle,' March 16, 1861, p. 241.

Sulphur in a state of combustion evolves sulphurous acid gas. This is sometimes employed as a fumigation in some obstinate cutaneous affections, especially *psoriasis inveterata,* which often continues about the joints, especially the elbow, when it has been cured in every other part. The employment of this requires caution, and on no account must the face be exposed to it, as it is irrespirable.

SULPHUR TRADE. Sulphur exists in Sicily, Iceland, Teneriffe, St. Vincent's, and some other places; but the expense of obtaining it from most of those countries is so great, that Sicily is almost the only source of supply. From that country England and France take more than 90 per cent. of the whole quantity exported. The average consumption of England in the five years, from 1820 to 1824, was 7080 tons. In 1825 the duty was reduced from 15*l.* to 10*s.* a ton, and in the following ten years the annual consumption averaged 15,140 tons; in 1837 it amounted to 37,486 tons. The Sicilian sulphur-mines are the property of individuals, and several English firms settled in Sicily are engaged in the trade. In 1836 M. Taix, a Frenchman, laid before the Sicilian government a project for establishing a company which was to have the exclusive right during ten years of purchasing Sicilian sulphur at fixed prices, on condition of spending 10,000*l.* a year in constructing roads, and exporting one-third of the quantity produced in Sicilian vessels. The British merchants becoming alarmed, the Sicilian government, in reply to the British ambassador, stated that no such project would be adopted. It would have been in direct contravention to certain commercial treaties between the two governments. The Sicilian government did, however, enter into a contract with M. Taix; and on the 4th of July, 1838, notice was given at Palermo that the monopoly would come into operation on the 1st of August ensuing. The negotiations respecting this monopoly were conducted with great secresy, and it came into operation so suddenly that twenty-four vessels lost their cargoes. The British lessees of mines, and all others, were compelled to produce only a fixed quantity of sulphur; prices rose from 6*l.* 10*s.* or 7*l.* to 13*l.* and 14*l.* per ton, and contracts could not be completed. At length the British government took very decided steps to put an end to a monopoly established in the face of commercial treaties: the coasts of Sicily and Naples were blockaded by our ships of war; and the Sicilian government, no longer daring to uphold the monopoly, accepted the mediation of the king of the French in adjusting the dispute with the British government. The monopoly was abolished in July, 1840, and a mixed English and Sicilian commission was appointed in November to investigate the claims of British subjects whose interests had been injured by it. The claims amounted to 65,610*l.*, of which 21,307*l.* was awarded; and as it was stipulated that the awards should bear interest at the rate of 6 per cent. so long as they remained unsettled, the Sicilian government agreed, in January, 1842, to pay them without any delay. The sulphur trade was thereupon placed on the same footing as before the date of the contract with M. Taix.

A correspondent of the *Times* newspaper, while noting and recording the exploits of Garibaldi in Sicily in 1860, turned aside to visit the principal sulphur district, and to give an account of the present mode of conducting the trade. The chief mines are at Villarosa, Santa Catalda, and Terra di Falco. The sulphur lies imbedded in tufa, gypsum, or limestone, mostly at the sides of mountains. Sometimes the vein is so thick as to require pillars of sulphur to be left to support the roof of the mine. The smelting, or preparation for market, used to be conducted in the open air; but as this injured the quality, and moreover tainted the air of the neighbourhood, another plan is now adopted. A round space is cleared on the side of a mountain, about sixty feet in diameter, with a high wall to bound it on the outer or lower side. An orifice in this side is formed, temporarily plastered over. The sulphur-stone is placed in regular layers on the open space, heaped up conically very high, and is well covered with the rubbish resulting from former smeltings. Fire is applied through a small opening, which is then closed up; and the stone burns for about three weeks, as much excluded from the air as possible. When the whole of the sulphur in the stone has become liquefied, the hole is tapped, and a black pitchy liquid runs out into troughs; this liquid cools to a yellow solid, clean or dirty according to its quality. The price of the sulphur thus obtained is greatly increased by the difficulty of transport. There is no road from the mines suitable for vehicles. Mules carry the sulphur to the nearest town, whence it is conveyed in two-horse carts to Girgenti.

SULPHURATION, or SULPHURING, is the process of bleaching employed to give whiteness to silk and woollens by exposing them to the fumes of burning sulphur. For this process a detached chamber, without a chimney, is made use of; but so constructed that, when required, a current of air may be passed through it. In sulphuring silk, about 100 pounds, stretched on perches, are placed at a height of nearly seven feet; and about two pounds of sulphur, reduced to coarse powder, are put into an iron pot containing a small quantity of ashes; the sulphur is fired in several places, and the chamber well closed to prevent the loss of sulphurous fumes; afterwards the windows are opened to let them escape and to dry the silk. In winter, after the smell of the sulphurous vapour has ceased, the windows are shut, and charcoal is burnt in the chamber, in order that the silk may be dried. By this operation the silk becomes perfectly white, and is rendered fit for subsequent operations. Woollen cloths are treated nearly in the same manner. Straw hats and bonnets are also sulphured.

SULPHURETTED HYDROGEN. [Sulphur.]

SULPHURIC ACID. [Sulphur.]

SULPHURIC ACID, *Medical Properties of.* This, which is regarded as the most potent of the mineral acids, is never taken internally in a concentrated state except by accident, or with the intention to commit suicide or murder. In such cases it acts as a violent corrosive poison, causing complete disorganisation of the tissues it comes in contact with, its course being obvious from the black and charred state of the parts. This effect it is thought to produce from its strong affinity to water, depriving the tissues of its elements, and leaving the carbon free. This peculiarity distinguishes poisoning by it from the other mineral acids. Notwithstanding the extensive destruction of important organs, such as the stomach, immediate death rarely results from it, but the patient lingers sometimes for days, and in some cases ultimately recovers.

Sulphuric acid is sometimes employed in an undiluted state as a caustic application to the bites of rabid animals, or to destroy warts or portions of the eyelids in entropium and ectropium.

In a considerably diluted state, if it be applied to the skin, it occasions a painful impression, followed by numbness and a contraction of the parts, and even whiteness, owing to the diminished calibre of the capillaries. But shortly the afflux of blood to the part recurs, and soon increases, so that the action of the vascular system appears to become more developed than before. As it is presumable that a similar series of actions takes place when received in a diluted form into the stomach, by bearing these phenomena in mind it is possible to explain its therapeutic influence in many of the cases where it is used.

Taken internally in a diluted but still strong state, it makes a powerful impression on the stomach, followed by an instantaneous sympathetic chill of the whole system: hence its power in checking hæmorrhage long before its particles can be received into the circulation and constringe the vessels by immediate contact with their sides. From the same cause it acts as a useful refrigerant in fevers and other inflammatory diseases when the animal temperature is too high. In many of the transient diseases of the skin attended with much heat and itching, a solution of sulphate of magnesia, with an addition of dilute sulphuric acid, quickly relieves them. It has also been given at a late stage of typhus in some mild diluent, such as barley-water. In combination with cinchona, it is of decided utility in *purpura hæmorrhagica.* Nothing save oxide of zinc so certainly checks the colliquative sweats which attend hectic fever as the compound infusion of roses. In chronic diarrhœa and dysentery it is also sometimes of service. Hæmorrhoidal fluxes are often restrained by its use. In some forms of dyspepsia it is a valuable tonic, and may be longer persevered with than any other mineral acid except phosphoric. In calculous diseases with a phosphatic diathesis, it is much to be commended, from the length of time it can be used. In such cases it is best given in infusion of camomile made with cold water. It is employed largely diluted as a gargle in the sore-throat of scarlet fever. Many cases of cutaneous diseases have been cured by the internal use of sulphuric acid. The aromatic sulphuric acid, called elixir of vitriol, has more tonic properties than the simple acid. A few drops of it, ten or twelve, in a cup of cold water, relieve very certainly the squeamishness of the stomach which is felt in the morning after an excess of wine. In case of poisoning by sulphuric acid, lime-water, calcined magnesia, or plaster from the wall, or a solution of soap, should instantly be given.

The *unguentum acidi sulphurici* is a most effectual application in obstinate cases of itch. It chars the linen.

SULPHURIC ETHER. [Ethyl.]

SULPHUROUS ACID. [Sulphur.]

SULTA'N, an Arabic word meaning "a despotic ruler, or a man who is the arbiter of the life and property of a set of men." It is the usual title of royalty among the Arabs and Turks. From sultán the Italians have made their *soldano*, and the Spaniards have their *sultán.* The lawful wife of a sultán, who has children by him, is called by us a sultana.

SUM (in the sense of integral). Before the organisation of the formal integral calculus, the isolated operations of integration which were attained were expressed in words borrowed apparently from the notion of indivisibles. [Cavalieri, in Biog. Div.] Thus the title of one of Halley's papers is 'An Easy Demonstration of the Analogy of the Logarithmic Tangents to the Meridian Line or Sum of the Secants.' Here the sum of the secants means what we should now denote by $\int \sec x.dx.$

SUM AND DIFFERENCE. There is no need to define the arithmetical meaning of these terms: a few words only are necessary to put them in their proper position in algebra. When quantities receive their proper algebraical signs, and those signs their interpretations [Algebra; Sign; &c.], they are said to be added to a quantity when they are allowed to produce their effect, and subtracted when they are allowed to produce a contrary effect. And when quantities are put together so that each produces its simple effect, they are said to be added together; while any parcel which is either withdrawn, or compensated by others of equal and opposite effects, is said to be subtracted. We are not here discussing principles, but settling terms; and it is enough if the notions appended to them be proper foundations for clear and good deduction; and an additional advantage if common ideas and received phraseology be also suited, provided that nothing be assumed from such ideas and phraseology to the prejudice of the dependence of the deduction upon the prescribed definitions.

To form a just idea of the property of any person, we take the sums which he owes away from his assets; that is, we take away, not his debts, but sums out of his assets equal to his debts. To say that this is taking away his debts would not be correct; for taking away his debts would be merely destroying his liabilities, without making his assets answerable: a person who himself pays another's debts takes them away. A court of justice which decides a claim against the assets of any one, annexes or puts on a liability; and this is in algebra *adding:* if the decision should be reversed on appeal, this liability to pay is removed, and this is in algebra subtracting. In the phrase "to gain a loss," the word "gain" is used in the preceding sense of simple adjunction: if it were as common to talk of losing a loss, the verb to lose would be used in the sense of to remove or to get rid of: the other form of the word would be less of a bull, for to *loose* a loss would be to detach it. In a third form, the idiom is still plainer; to *release* [from] a loss would be precisely the idea of algebra, answering to subtracting a loss.

SUM, SUMMATION. In the articles Integration, Finite, and Progression, some ideas and rules are given upon the subject of the summation of a finite number of terms of a series; and in Series will be found examples of the inverse process of development. In the present article we are to give some account of the methods of actual summation which are in use in the higher branches of mathematics; referring for the demonstrations to the Differential Calculus in the 'Library of Useful Knowledge' (cited by the letters D. C.). We shall dwell upon this at greater length than would appear to be altogether in keeping with the extent of the articles above cited; the reason being that many persons to whom the following rules may be practically useful never hear of them because they are locked up in Treatises on the Differential Calculus, or in works which are not generally read. The merest elements of differentiation and integration are enough to enable a beginner to use results the *proof* of which must be reserved for a more advanced stage of his progress.

1. When the terms of a series are alternately positive and negative, as in $a_0 - a_1 + a_2 -$ &c., the sum of the series *ad infinitum* may thus be expressed [DIFFERENCE] (D. C., pp. 556–560) :—

$$\frac{a_0}{2} - \frac{\Delta a_0}{4} + \frac{\Delta^2 a_0}{8} - \frac{\Delta^3 a_0}{16} + \ldots\ldots$$

which is frequently more convergent than the series itself; in fact, the less convergent the series is, the more convergent is the transformation. Dr Hutton's method of obtaining the transformed series is as follows: —Take a number of the successive sums a_0, $a_0 - a_1$, &c., and let

$$\text{s}_0 = 0\,,\ \text{s}_1 = a_0\,,\ \text{s}_2 = a_0 - a_1\,,\ \text{s}_3 = a_0 - a_1 + a_2\,,\ \&\text{c.}$$

Take the half sum of s_0 and s_1, the half sum of s_1 and s_2, the half sum of s_2 and s_3, &c. Let these be T_0, T_1, T_2, &c. Repeat the process: take the mean of T_0 and T_1, that of T_1 and T_2, &c., which call U_0, U_1, &c. Take the mean of U_0 and U_1, that of U_1 and U_2, &c., which call V_0, V_1, &c. Then the set S_0, T_0, U_0, V_0, &c., will severally approach nearer and nearer to the series required; in fact

$$\text{T}_0 = \frac{a_0}{2},\ \text{U}_0 = \frac{a_0}{2} - \frac{\Delta a_0}{4},\ \text{V}_0 = \frac{a_0}{2} - \frac{\Delta a_0}{4} + \frac{\Delta^2 a_0}{8},\ \&\text{c.}$$

It would however be somewhat easier to proceed as follows:—having formed differences as far as may be thought necessary, say up to $\Delta^n a_0$, take half $\Delta^n a_0$ from $\Delta^{n-1} a_0$, half the result from $\Delta^{n-2} a_0$, half the result from $\Delta^{n-3} a_0$ and so on until a_0 has been used: after which halve the result again. In either case we need not begin at the beginning of the series: if it be more convenient to begin after a_{10} let $\text{A}_{10} = a_0 - a_1 + \ldots\ldots - a_9 + a_{10}$, and calculate this separately: then calculate $a_{11} - a_{12} + \ldots\ldots$ from the rule, and we have $\text{A}_{10} - (a_{11} - a_{12} + \ldots)$ for the series required. The following is an instance from Dr. Hutton ('Tracts,' vol. i., p. 191), the series being $1 - \frac{1}{2} + \frac{1}{3} - \frac{1}{4} + \ldots\ldots$

Sums.	The several orders of means.					
1						
0·5						
833333						
583333						
783333						
616666	688095					
759524	607024	692560	693056			
634524	690080	693552	693205	693131	693144	
745635	695635	692858	693110	693158	693150	693147
645635	691090	693362	693173	693142		
736544	694878	692984				
653211						

The result is ·693147, which is correct to the sixth place, and is more than could be got from the series itself by actual summation of a million of its terms. Dr. Hutton begins in forming the means with $1 - \frac{1}{2} + \ldots\ldots + \frac{1}{6}$: we shall therefore try the other method, beginning with $\frac{1}{7}$.

Terms.	Orders of differences.				
	−	+	−	+	−
·142857	17857				
·125000	13889	3968			
·111111	11111	2778	1190	432	
·100000	9091	2020	758	253	179
·090909	7576	1515	505		
·083333					

2)−179

− 89·5
432

2)521·5

260·8
−1190

2)−1450·8

− 725·4
3968

2)4963·4

2346·7
−17857

2)−20208·7

−10101·9
142857

2)152958 9

76479·5

$1 - \frac{1}{2} + \ldots - \frac{1}{6} =$ ·6166666
·0764795

·6931461

This last process will be found on trial the easier of the two.

2. The sum of the series $a_0 - a_1 + a_2 -$ &c. *ad infinitum* may be thus expressed (D. C., p. 555) :—

$$\frac{a_0}{2} - \frac{a_0'}{4} + \frac{a_0'''}{48} - \frac{a_0^{\text{v}}}{480} + \frac{17a_0^{\text{vii}}}{80640} - \&\text{c.}$$

where a_x, a function of x, generates the several terms by making $x = 0, 1, 2$, &c., in succession, and a_0', a_0''' a_0^{v}, &c., mean the values of the odd differential co-efficients of a_x when x is $= 0$. This transformation is useful when the values just mentioned are not considerable. Another form, which is sometimes more convenient, is—

$$\frac{a_0}{2} - \frac{a_0'}{4} + \frac{a_0'''}{2\,[4]} - \frac{3a_0^{\text{v}}}{2\,[6]} + \frac{17a_0^{\text{vii}}}{2\,[8]} - \&\text{c.}$$

where $[m]$ means $1\,.\,2\,.\,3 \ldots\ldots m$. In the instance before us, and that we may begin from the same term as before, let

$$a_x = \frac{1}{7+x},\ a_0 = \frac{1}{7},\ a_1 = \frac{1}{8},\ \&\text{c.}$$

$$a_0 = -\frac{1}{7^2},\ a_0''' = -\frac{[3]}{7^4},\ a_0^{\text{v}} = -\frac{[5]}{7^6},\ a_0^{\text{vii}} = -\frac{[7]}{7^8};$$

whence the series required from and after $\frac{1}{7}$ is—

$$\frac{1}{14} + \frac{1}{4\,.\,7^2} - \frac{1}{2\,.\,4\,.\,7^4} + \frac{3}{2\,.\,6\,.\,7^6} - \frac{17}{2\,.\,8\,.\,7^8}.$$

Call these terms (1), (2), &c., and begin with $\frac{1}{2} + \ldots - \frac{1}{6}$, or ·616666 ....: we have then—

	·6166666667
(1)	·0714285714
	·6880952381
(2)	·0051020408
	·6931972789
(3) −	·0000520616
	·6931452173
(4)	·0000021250
	·6931473423
(5) −	·0000001843
	·6931471580
True Answer	·6931471806

The result of this comparatively easy process is as correct as the summation of fifty millions of terms of the series.

3. The sum of any large number of terms of a series may be found by summing the whole series *ad infinitum*, then doing the same with the terms following the last term which is to be retained, and subtracting the second result from the first.

4. The sums of such series as are included under $1^{-n} + 2^{-n} + 3^{-n} +$ &c., such as

$$1 + \frac{1}{4} + \frac{1}{9} + \ldots,\ 1 + \frac{1}{8} + \frac{1}{27} + \&\text{c.}$$

continued *ad infinitum*, may be given for reference in the following table. The first term will presently be explained. More will be found in D. C., p. 554.

n.	Sum of Series.
1	·5772156649015329 + log ∞
2	1·6449340668482264
3	1·2020569031595943
4	1·0823232337111382
5	1·0369277551433700
6	1·0173430619844491
7	1·0083492773819227
8	1·0040773561979443
9	1·0020083928260822
10	1·0009945751278180
11	1·0004941886041194
12	1·0002460865533080

The first line means that the sum of the series is infinite, but that the expression for a large number of terms contains the logarithm of that number, which being removed, the rest of the expression approximates as the number of terms increases, to ·577215 ....

5. The series $1^{-n} - 2^{-n} + \ldots$ is connected with $1^n + 2^n + \ldots$ by the following simple law:—

$$1^{-n} - 2^{-n} + 3^{-n} - \ldots = \left(1 - \frac{1}{2^{n-1}}\right)(1^{-n} + 2^{-n} + 3^{-n} + \ldots)$$

6. The sum $a_0 + a_1 + a_2 + \ldots$ *ad infinitum* may be thus transformed:—

$$\int_0^\infty a_x dx + \frac{1}{2}\,a_0 - \frac{1}{6}\,\frac{a_0'}{2} + \frac{1}{30}\,\frac{a_0'''}{[4]} - \frac{1}{42}\,\frac{a_0^{\text{v}}}{[6]} + \&\text{c.}$$

where the notation is as previously explained, and $\frac{1}{6}$, $\frac{1}{30}$, &c., are the series of NUMBERS OF BERNOULLI. To apply this, for example, to

$1^{-2}+2^{-2}+3^{-2}+\ldots$, it will be convenient to begin from some term which will make the series more convergent. Let $a_x=(10+x)^{-2}$: we have then for $10^{-2}+11^{-2}+\ldots$ the following:—

$$\frac{1}{10}+\frac{1}{2}\,\frac{1}{10^2}+\frac{1}{6}\,\frac{1}{10^3}-\frac{1}{30}\,\frac{1}{10^5}+\frac{1}{42}\,\frac{1}{10^7}-\&c.,$$

which may be easily calculated, and the preliminary series $1^{-1}+\ldots+9^{-2}$ may then be added.

7. The finite series $a_0+a_1+a_2+\ldots+a_{x-1}$ (x terms) is thus transformed (D. C., p. 266):—

$$\int_0^x a_x\,dx-\frac{1}{2}(a_x-a_0)+\frac{1}{6}\,\frac{a_x'-a_0'}{2}$$
$$-\frac{1}{30}\,\frac{a_x'''-a_0'''}{[4]}+\frac{1}{42}\,\frac{a_x^{\mathrm{v}}-a_0^{\mathrm{v}}}{[6]}-\frac{1}{30}\,\frac{a_x^{\mathrm{vii}}-a_0^{\mathrm{vii}}}{[8]}+\&c.,$$

in which the detached coefficients are again the numbers of Bernoulli. Or, if the sum of the series *ad infinitum* be known, s, the preceding may be expressed as follows:—

$$s-\int_x^\infty a_x\,dx-\frac{1}{2}\,a_x+\frac{1}{6}\,\frac{a_x'}{2}-\frac{1}{30}\,\frac{a_x'''}{[4]}+\&c.$$

But when the complete series is divergent, the set of terms $a_0+a_1+\ldots+a_{x-1}$ may be thus expressed:—

$$c+\int_0^x a_x\,dx-\frac{1}{2}\,a_x+\frac{1}{6}\,\frac{a_x'}{2}-\frac{1}{30}\,\frac{a_x'''}{[4]}+\&c.,$$

where c must be determined by an instance. Thus if we make $a_x=(1+x)^{-1}$ we have for $1+2^{-1}+\ldots+x^{-1}$ the following series:—

$$c+\log^{*}(1+x)-\frac{1}{2}\,\frac{1}{1+x}-\frac{1}{12}\,\frac{1}{(1+x)^2}+\frac{1}{120}\,\frac{1}{(1+x)^4}-\&c.$$

Add $(x+1)^{-1}$ to both sides, and write $x-1$ for x, which gives for $1^{-1}+\ldots+x^{-1}=$

$$c+\log x+\frac{1}{2x}-\frac{1}{12x^2}+\frac{1}{120x^4}-\&c.$$

To determine c, choose such a number for x as shall make this series convergent, say $x=10$. Calculate $1^{-1}+\ldots+10^{-1}$, term by term, which is easily done, and equate the sum to

$$c+2{\cdot}302585093+\frac{1}{20}-\frac{1}{1200}+\frac{1}{1200000}-\&c.,$$

which gives $c={\cdot}5772156\ldots$, the number mentioned at the head of the table for series of inverse powers already given. With the value of c thus determined, and a sufficient table of logarithms, the larger the number of terms in $1^{-1}+\ldots+x^{-1}$, the more easily is its approximate value calculated.

8. The series $\log 1+\log 2+\ldots+\log x$ is of sufficient importance to have an article to itself. Make $a_x=\log(1+x)$, and proceed as in the last example, which will give for $\log(1.2.3\ldots x)$ the following series:—

$$c+\log x.x-x+\frac{1}{2}\log x+\frac{1}{12x}-\frac{1}{360x^3}+\ldots$$

c might be determined as before, but a particular mode of investigation shows it to be $\log(\sqrt{2\pi})$, where $\pi=3{\cdot}14159\ldots$, as usual. This gives

$$1.2.3\ldots x=\sqrt{2\pi x}\;x^x.\;\epsilon^{-x+\frac{1}{12x}-\frac{1}{360x^3}+\&c.}$$

a result of the greatest use, particularly in the more complicated applications of the theory of probabilities.

9. The series $0^n+1^n+2^n+\ldots+x^n$, in which $a_x=x^n$, n being integer and positive, is by the case of § 7, and adding x^n to both sides,

$$c+\frac{x^{n+1}}{n+1}+\frac{x^n}{2}+\frac{1}{6}\,\frac{nx^{n-1}}{2}-\frac{1}{30}\,\frac{n(n-1)(n-2)x^{n-3}}{2.3.4}+\&c.;$$

but this vanishes when $x=0$, whence c must be taken accordingly in every instance. To take an example which shall require a little extension of the series beyond the terms used above, let it be required to find $0^7+1^7+\ldots+x^7$. Looking at the article NUMBERS OF BERNOULLI, we find a supply of coefficients in

$$\frac{1}{6}\quad\frac{1}{30}\quad\frac{1}{42}\quad\frac{1}{30}\quad\frac{5}{66}\quad\frac{691}{2730},$$

and the sum required is

$$c+\frac{x^8}{8}+\frac{x^7}{2}+\frac{1}{6}\,\frac{7x^6}{2}-\frac{1}{30}\,\frac{7.6.5x^4}{2.3.4}+\frac{1}{42}\,\frac{7.6.5.4.3x^2}{2.3.4.5.6}$$
$$-\frac{1}{30}\,\frac{7.6.5.4.3.2.1}{2.3.4.5.6.7.8},$$

which vanishes when $x=0$, whence

$$c+\frac{1}{30}\,\frac{7.6.5.4.3.2.1}{2.3.4.5.6.7.8}=0,$$

and the rest may be reduced to

$$\frac{x^8}{8}+\frac{x^7}{2}+\frac{7x^6}{12}-\frac{7x^4}{24}+\frac{x^2}{12},$$
$$\text{or}\qquad(3x^8+12x^7+14x^6-7x^4+2x^2)\div 24.$$

SUMACH, or SWAMP SUMACH (*Rhus Toxicodendron*), a North American shrub, possessing peculiar properties, from which it has been named also the Trailing Poison Oak. The leaves, which are trifoliate, thin, shining when fresh, of a dark-green colour, are the only parts officinal in this country. But the leaves, branches, and flowers contain a milky juice which blackens on exposure to the air, and may be used as an indelible ink when applied to cotton or linen. Besides this very acrid milk, the plant, when not exposed to the sun's rays, by growing in the shade, or during the night, exhales a hydrocarburetted gas, which acts very potently on persons of a peculiar susceptibility, when exposed to it. In two or three days after touching or being very near the plant, the skin inflames and swells, being attended with intense burning pain. If the face be affected, the eye-lids are so tumefied as to close up the eyes; and the whole head is swelled and covered with little blisters containing serum. Occasionally the whole body is enormously swollen and covered with similar vesicles. When the inflammation and swelling have subsided, the skin desquamates, and an intolerable itching is felt for several days afterwards. These symptoms closely resemble erysipelas, and are moderated by treatment suited to that complaint. Professor Barlow states that the best application is a weak aqueous solution of bichloride of mercury. All persons however should avoid touching any sumach which has milky juice.

The leaves, or an extract of the inspissated juice of this plant, have been recommended in several diseases, particularly herpes, paralysis, and consumption. It is little used in this country, but it appears entitled to some confidence in local paralysis, such as that of the jaw. It must be given with caution, as large doses act like narcotico-acrid poisons.

SUMBUL, written also Sunbul, is a generic term applied to many fragrant roots, one or more of which have been already noticed under SPIKENARD. What is now to be noticed is a root recently introduced into medical practice, of which there are two, perhaps three varieties, the source of none of which is accurately known, though conjectured to be the produce of some umbelliferous plant, to which the name of *Angelica moschata* has been given. One is designated Russian sumbul, another, Indian sumbul; while a third is called Cathayan sumbul, which perhaps scarcely differs from the first kind, which is said to reach Moscow through Kiachta, the same channel as the Russian rhubarb. The Russian is the most powerful in odour, which is more or less musky. The taste is bitter and slightly acrid. The analysis shows it to contain a volatile oil, two balsamic resins, one soluble in ether, the other in alcohol, with wax, starch, &c., and a peculiar acid termed sumbulic. It yields its properties to alcohol or ether; it is also given in powder, watery infusion, decoction, or extract. The balsamic resins and oil impart a stimulating power to it, which renders it useful as an antispasmodic, and it is especially available in hysterical affections; and like other medicines of the same class, it would appear to be sedative, as it calms nervous restlessness and procures sleep. It has also been recommended in dropsy and atrophy.

SUMBULIC ACID. [ANGELIC ACID.]

SUMMARY CONVICTION. [LAW, CRIMINAL.]

SUMMARY JURISDICTION. [JUSTICES OF THE PEACE.]

SUMMER. [WINTER, &c.]

SUN (Latin, *sol*; Greek, ἥλιος, Hēlios). In the present article we confine ourselves to the astronomical characters of the sun's orbit, and to what we know of its physical constitution. For more particulars on the measurement of time, see TIME; on chronology as dependent on this body, and on the more common characters of its motion, see YEAR. See also MOON; SEASONS; ASTRONOMY; ZODIAC (on mythology); ZODIACAL LIGHT; TWILIGHT; &c.

It is needless to say that if the utility of the subject of an article were to determine its length, the one we are now commencing ought in justice to occupy several volumes of the work: were we, however, seriously to mete out the importance of the sun in columns of a Cyclopædia, our panegyric would not be more quaint than that of Sir John Hill, who says that this luminary is "enough to stamp a value on the science to which the study of it belongs." In relation to astronomy this is particularly true; for it would be possible to preserve life on the earth, and to keep order, without any knowledge of the moon, planets, or stars; but to do this without any acquaintance with the sun's motions would be absolutely impossible. The source of light and heat, and through them of the alternations of the vegetable world, is, in the highest secondary sense, the giver and sustainer of life; but this very importance ensures names to so many results of solar phenomena, that the present article is stripped of details, by their entering more appropriately into others.

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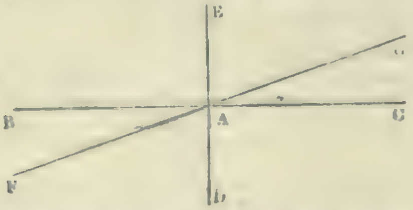
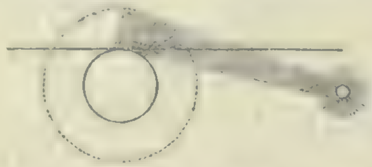
[*] The Naperian logarithm, which is always used in mathematical investigations, unless the contrary be expressed. It is 2·302585093 × comm. log.

The motions of the sun are in fact those of the earth, written in the heavens. If the diurnal motion of the earth were stopped, the sun would appear to move slowly among the stars, from west to east, at the rate of about twice its own diameter in twenty-four hours by the clock. This [Motion] is the consequence of the orbital motion of the earth, which is communicated in appearance to the sun. If the earth's orbital motion were stopped, the diurnal motion continuing as usual, the sun would appear to move round daily, from east to west, as at present; but since there would then be no motion of that body among the stars, those stars which are at any one time hidden by the daylight would always be hidden, and the face of the heavens at any given hour of night would be the same at all times of the year. The effect of the orbital motion of the earth combined with the diurnal motion is that the solar day, or the interval between two meridian passages of the sun, is a little longer than the sidereal day (about four minutes), or than the actual revolution of the earth; so that all the stars have their turn, and every star in the course of the year comes on the meridian at every period of the natural or solar day. [Synodic; Time.]

The great phenomena of day and night are attended with very different circumstances in different parts of the globe. We are not speaking now of the high polar regions, north and south, in which the sun never sets for days together, but of those parts of the earth in which there is actual appearance and disappearance of the luminary, or real day and night. Let us take the day of the vernal equinox as a specimen, when the sun is in the equator (we presume in our reader a knowledge of the terms and notions in Sphere, Doctrine of the). If we take one fixed line to represent the horizon of different places, as B A C, the sun will rise to a place on the equator so as to move along the circle D A E, and to come directly up from the horizon; while at a place near the pole it will move, relatively to the horizon (still B A C), along the circle F A G. Now the first evidence which the sun gives of its approach is this (the diagram, though of very distorted dimensions, may be of use): before it has risen above the horizon of a place, so as to be visible, it can throw its rays into the atmosphere above the place, which atmosphere reflects something both of light and heat to the place itself. This period is called the twilight, and it is said that there is more or less of twilight as long as the sun is not more than 15° below the horizon; though certainly the twilight which saves candle-light does not last so long. But be the number of degrees which are allowed to twilight more or less, it is obvious that at the equator, where the whole of the sun's way is made directly to or from the horizon, the intermediate period of twilight must be much shorter than at a place near the pole, where the motion towards the horizon is very oblique, instead of being all ascent, as before rising, or descent, as after setting. The consequence is well known: in the tropics, the warning is short, and soon after the light begins to break the sun makes its appearance, and it is broad and hot day; while after the setting the light as soon disappears, and it is dark night. With us, on the contrary, and still more in higher northern latitudes, there is a long warning of the approach of the luminary before the sunrise, and a long remembrance of it after sunset. In all climates the transition from day to night is broken by the two circumstances mentioned in Seasons. In the same article it is pointed out that the heat received during the winter and summer halves of the year is the same over the whole earth.





Immediately after sunrise, the form of the luminary appears somewhat elliptic, the horizontal diameter being longer than the vertical one. This is the effect of Refraction, which varies so rapidly near the horizon that the upper end of the vertical diameter is less elevated than the lower end by a sensible quantity, while the two ends of the horizontal diameter are equally elevated. The same phenomenon occurs with the moon, when rising at the full, and would also be seen in the planets, if they were large enough in appearance. It must also be noted that both sun and moon appear larger when near the horizon; but this, as to the sun, is delusion, since when measured with instruments its apparent diameter is the same at all parts of the day. It is true that both bodies, when in the zenith, are nearer to the spectator than when in the horizon, by what may be called without error a semidiameter of the earth; the moon is near enough to show the effect of this in instrumental measurements of its diameter, but it is not so with the sun.

Before looking at what we know of the physical appearances of the sun, its distance from the earth must be mentioned, to which we may add at once the other elements of its orbit. Its equatorial horizontal Parallax, at its mean distance, is 8″·5776, and its apparent semidiameter 16′ 0″·9. It is then distant from the earth by 24,000 semidiameters of the earth, or about 95,000,000 miles. Its diameter is 111½ times as great as that of the earth, or upwards of 880,000 miles; and its bulk is 1,300,000 times as great as that of the earth. But its mass, as determined from its action on the planets, is only 355,000 times as great as that of the earth; whence its average density is only one-quarter of that of the earth. But this last result takes into the body of the sun all that is seen of it: if the surmise presently to be mentioned, of its having a luminiferous atmosphere of considerable extent, be well founded, the real body of the sun may have as much density as the earth, or more. It revolves on its axis in 25½ of our mean solar days; according to Delambre, in 25·01154 days: the axis being inclined to the ecliptic at an angle of 82½°.

The ecliptic is the circle in which the sun appears to move, in common language. In strictness, however, the earth does not move round the sun in a true plane, though it does so very nearly. The centre of gravity of the earth and moon (a point near the earth) does much more nearly describe a plane; that is, a spectator situated at that point would more nearly see the sun move in a great circle than we do. But to us, the sun is sometimes on one side and sometimes on the other of this mean ecliptic, and therefore generally has some *latitude*, though a very small one: the column entitled "the Sun's latitude" in 'The Nautical Almanac' is a puzzle to those readers whose astronomy is drawn from the usual elementary writings: in truth, it is only a fraction of a second, and the sun crosses the mean ecliptic twice in every lunation. The obliquity of the mean ecliptic, for January 1, 1860, is 23° 27′ 27″·38, and it is diminishing yearly by 0″·457: thus this same obliquity for January 1, 1842, is 23° 27′ 35″·60. If this diminution could go sufficiently far, it would in time bring the ecliptic and equator to coincidence, or equalise days and nights all over the world; and if it could be held to have continued long enough, would entitle us to presume that the poles were once in the plane of the ecliptic, or that every part of the earth went through all gradations in a year from equal days and nights to a polar day and a polar night. But the cause of this diminution of the ecliptic is known from the theory of gravitation; and it is also known that, under existing causes, it cannot be permanent, but must diminish in quantity and finally turn into an increase before its effect has amounted to many degrees. Persons acquainted with the phenomena of the heavens, but not with the results of the theory of gravitation, remembering the fact of tropical productions being found buried in high latitudes, sometimes imagine that they can look back to the time when the poles were so near the ecliptic, that these same high latitudes were within the tropics. This, however, is a pure fancy, and they had better imagine another cause; the one they think of will not do.

The mean longitude of the sun, at Greenwich mean noon on the 1st of January of the year $1800+t$, may be determined from

$$280^\circ\ 53'\ 32''\cdot75 + 27''\cdot605844t + \cdot0001221805t^2 - 14'\ 47''\cdot083f,$$

where f is the remainder of t divided by 4, or 4 if the remainder be 0; that is, the number of years after the *Julian* leap-year, or after the *Gregorian* leap-year for all years after 1804. The mean motion in longitude in a mean solar day is 59′ 8″·33.

The excentricity of the sun's orbit is ·016783568 (according to Laplace, ·01685318), or the greatest and least distances of the sun from the earth are in the proportion of 1·017 to ·983, or as 30 to 29, or more nearly as 91 to 88. The greatest equation of the centre [Time] is 1° 55′ 27″·3. The excentricity diminishes by ·00004163 in a century.

The mean longitude of the perigee, at noon, January 1, 1801, was 279° 30′ 5″·0. It has a real yearly increase of 11″·8, which, with the precession of the equinoxes, makes an increase of longitude of 61″·9.

The appearance of the sun is simply that of a ball of intense light, such as the human eye cannot bear, unless a hazy atmosphere or a dark glass be used as a screen. This light is so strong, that the brightest flames which human art can produce, when held before the sun, disappear, and ignited solids become dark spots. "The ball of ignited quicklime," says Sir J. Herschel, "in Lieut. Drummond's oxy-hydrogen lamp, gives the nearest imitation of the solar splendour which has yet been produced. The appearance of this against the sun was however, as described," merely a dark spot, "in an imperfect trial at which I was present. The experiment ought to be repeated under favourable circumstances." A very small portion of the rays collected into one spot [Burning-Glasses] is sufficient to melt metals. On examining the face of the sun with a telescope (of course with a dark glass before the eye), two circumstances are observed. The disc is not uniformly bright. "The ground is finely mottled," to use the words of the observer just quoted, "with an appearance of minute dark dots, or *pores*, which, when attentively watched, are found to be in a constant state of change. There is nothing which represents so faithfully this appearance as the slow subsidence of some flocculent chemical precipitates in a transparent fluid, when viewed perpendicularly from above; so faithfully, indeed, that it is hardly possible not to be impressed with the idea of a luminous medium intermixed, but not confounded, with a transparent and unluminous atmosphere, either floating, as clouds in our air, or pervading it in vast sheets and columns like flame, or the streamers of our northern lights." The mind is lost in wonder at the idea of such a body of luminous material; but it is important to remember that living, as we must, under an atmosphere, we cannot positively assert anything as to what may take place beyond it. It is possible, though not very probable, that we should neither feel sensible of light nor heat, if we could meet the sun's rays before they have entered the air.

The other circumstance which is noticed on the sun's disc is the existence of black spots, by the regular motion of which the rotation of the body on its axis has been determined. These spots are of various irregular shapes, and are always surrounded by a border or penumbra, not so dark as the spot. They are of various sizes, from the least visible to the twentieth part of the sun in diameter. In their neighbourhood are frequently observed streaks on the disc more luminous than the rest, called *faculæ*, in which streaks spots frequently begin their appearance. The spots themselves alter in size, and gradually vanish, lasting various times, from a few days to six or seven weeks; the borders approaching each other in a manner which calculation shows must answer to hundreds of miles a day. Various theories have been invented to account for them, but none which has any appearance of probability except that of W. Herschel ('Phil. Trans.,' 1801). He supposes that the sun has an atmosphere of greater density and depth than that of the earth; and that above this atmosphere, or else mixed with the higher strata of it, is another atmosphere of self-luminous clouds, of very variable depth, sometimes showing the lower atmosphere uncovered, which last reflects the light of the luminous atmosphere above it. A spot on the sun is a portion of the body of the sun itself, laid bare by some commotion which removes both atmospheres, or the greater portion of them: the penumbra round the spot, its never-failing attendant, arises from the ridges of the lower atmosphere, which form the banks of the opening. The faculæ, and general mottled appearance of the sun, arise from the luminous atmosphere having waves or ridges. From some measures of the light of different parts of the sun, Herschel thought that the non-luminous atmosphere reflects a little less than one-half the light it receives from the luminous atmosphere, and the solid body of the sun less than one tenth. He also supposed that the presence of spots and other disturbances indicated a large formation of heat and light in the sun, and was a prognostic of hot weather and fine seasons. This he imagined he had verified by such comparisons as existed of the state of the sun at different times with the prices of wheat immediately following: he found that, as far as his data went (and he gives a proper warning as to their insufficiency), the price of wheat always rose when the sun was without spots, and fell when they began to reappear. We have not heard of any extensive attempt to verify or refute this theory; but so far as the hypothesis of the two atmospheres is concerned, it is one of high probability: we could hardly ask for a likely result of such a combination which does not actually make its appearance. If it be correct, the sun may very possibly be a globe habitable by living beings, perpetually illuminated by its upper atmosphere, the lower atmosphere preventing too much of either light or heat from reaching them.

The most important result connected with modern researches on the solar spots is due to Schwabe, a German astronomer, who, by perseveringly observing the sun on every day that he was visible between the years 1826 and 1856, finally discovered that the number visible on the disc in the course of a year is subject to a periodic variation, passing through the cycle of its values in successive intervals of about eleven years. Shortly afterwards M. Lamont, Director of the observatory at Munich, discovered that the diurnal variation of the magnetic needle is subject to a corresponding period of equal duration. The researches of Schwabe have been confirmed by Mr. Carrington and other recent observers of the solar spots. Professor Wolf of Zurich, having carefully compared all the recorded observations of the spots, has also discovered unequivocal evidence of the existence of a law in the frequency of their appearance on the solar disc. The duration of the period, as might be expected from the imperfect nature of the observations, is found by Professor Wolf to be subject to considerable irregularities, but on the whole, the observations plainly indicate a recurrence in successive cycles of nearly the same number of spots visible on the disc in the course of a year. The following table, constructed by Professor Wolf from the recorded observations of the spots, exhibits the relative number of spots visible during each of the last 112 years:—

Year.	Relative Number of Spots Visible.	
1749	63·8	
1750	68·2	Maximum.
1751	40·9	
1752	33·2	
1753	33·1	
1754	13·8	
1755	6·0	Minimum.
1756	8·8	Minimum.
1757	30·4	
1758	38·8	
1759	48·6	
1760	48·9	
1761	75·0	Maximum.
1762	50·6	
1763	87·4	Maximum.
1764	34·5	
1765	23·0	
1766	17·5	Minimum.
1767	33·6	
1768	52·2	
1769	85·7	Maximum.
1770	79·4	
1771	73·2	
1772	49·2	
1773	39·8	
1774	47·6	
1775	27·5	Minimum.
1776	35·2	
1777	63·0	
1778	94·8	
1779	99·2	Maximum.
1780	72·6	
1781	67·7	
1782	33·2	
1783	22·5	
1784	4·4	Minimum,
1785	18·3	
1786	60·8	
1787	92·8	
1788	90·6	Maximum.
1789	85·4	
1790	75·2	
1791	46·1	
1792	52·7	
1793	20·7	
1794	23·9	
1795	16·5	
1796	9·4	
1797	5·6	
1798	2·8	Minimum.
1799	5·9	
1800	10·1	
1801	30·9	
1802	23·3	
1803	50·0	
1804	70·0	Maximum.
1805	50·0	
1806	30·0	
1807	10·0	
1808	2·2	
1809	0·8	
1810	0·0	Minimum.
1811	0·9	
1812	5·4	
1813	13·7	
1814	20·0	
1815	35·0	
1816	45·5	Maximum.
1817	43·5	
1818	34·1	
1819	22·5	
1820	8·9	
1821	4·3	
1822	2·9	
1823	1·3	Minimum.
1824	6·7	
1825	17·4	
1826	29·4	
1827	39·9	
1828	52·5	
1829	53·5	
1830	59·1	Maximum.
1831	38·8	
1832	22·5	
1833	7·5	Minimum.
1834	11·4	
1835	45·5	
1836	96·7	
1837	111·0	Maximum.
1838	82·6	
1839	68·5	
1840	51·8	
1841	29·7	
1842	19·5	
1843	8·6	Minimum.
1844	13·0	
1845	33·0	
1846	47·0	
1847	79·4	
1848	100·4	Maximum.
1849	95·6	
1850	64·5	
1851	61·9	
1852	52·2	
1853	37·7	
1854	19·2	
1855	6·9	
1856	4·2	Minimum.
1857	21·6	
1858	50·9	
1859	96·4	
1860	98·6	

A telescope of six inches aperture has been recently fitted up by the Royal Society, at the Kew Observatory, under the superintendence of Mr. De la Rue, for the purpose of taking daily photographic delineations of the sun's surface. The experiment has been attended with complete success, and important results may be expected from the comparison of a series of such records.

The origin of the heat and light of the sun is one of the most obscure points of astronomy. The most recent speculations on the subject are due to Professor William Thomson of Glasgow, who supposes a zone of meteors to circulate around the sun, within the orbit of Mercury, and to be falling gradually upon his surface in consequence of the resistance offered to them by the solar atmosphere. According to this theory, the solar light and heat are generated by the mechanical impact of the meteors on the sun's surface. The existence of a solar atmosphere may be considered to be established beyond all doubt by the corona seen during total eclipses of the sun, and by the fact, that the red prominences seen on such occasions have been observed in several instances to be *isolated* from the moon's limb. That these prominences are solar and not lunar phenomena has been satisfactorily proved by the numerous observations of the total eclipse of 1860, and more especially by the admirable photographs of the phenomenon taken by Mr. De la Rue with the Kew photo-heliograph at Miranda del Ebro. [Solar Eclipse.]

SUN, ECLIPSES OF. [Solar Eclipse.]

SUNDAY, the first day of the week. [Week.] Besides the name of "Sunday" (*dies solis*), it was called by the early Christians "the Lord's day" (*ἡ ἡμέρα ἡ κυριακή*, *dies dominicus*, or simply *κυριακή*, *dominica*) from its being the day on which the resurrection of Christ took place; and it was kept sacred in commemoration of that event. [Sabbath.] The mode of keeping it appears to have varied with the circumstances of the Christians. In the first ages it is very improbable that they abstained entirely from worldly business, as the time of many of them was not at their own command. They seem, however, as far as it was practicable, to have devoted the day to religious worship. For this purpose they were accustomed to assemble before daybreak; and we may infer from passages in the Acts, Epistles, and in Pliny's celebrated 'Letter to Trajan,' that singing hymns, reading the Scriptures, prayer, preaching, and the celebration of the Lord's supper, formed parts of these services.

We have a few notices of the mode of keeping the Sunday during the first three centuries. As early as the end of the second century, abstinence from worldly business seems to have been customary. (Tertullian, 'De Orat.', c. 23.) It was accounted a day of rejoicing, a feast and not a fast, and to fast upon this day was deemed unlawful. Upon it the Christians prayed standing, instead of kneeling, to intimate the elevation of their hopes through their Lord's resurrection. The public worship of the Christians on the Sunday in the first two centuries is described by Justin Martyr ('Apolog.'), whose account is particularly interesting, and by Tertullian ('Apolog.', c. 39; compare Euseb., 'Hist. Ecc.' iii. 3, and iv. 23).

As soon as the Christian religion came to be recognised by the state, laws were enacted for the observance of the Sunday; Constantine (in 321) ordered the suspension of all proceedings in the courts of law, except the manumission of slaves, and of all other business except agricultural labour, which was allowed in cases of necessity ('Cod. Justin.', iii., tit. 12, § 2, 3; 'Cod. Theodos.', viii., tit. 8, § 1, 3); and, as Eusebius tells us ('Vit. Const.,' iv., 18, 19, 20), he forbade all military exercises on Sunday. The laws of Constantine were repeated by subsequent emperors, with additions, of which one of the most important is that of Theodosius II. (in 425), by which the games and theatrical exhibitions were forbidden on Sunday. ('Cod. Theodos.' xv., tit. 7, § 1, 5.) The most strict of these laws is that of Leo and Anthemius. (460, 'Cod. Justin.', iii., tit. 12, § 8.) It should be observed that the provisions of most of these laws extend to all the principal sacred days observed by the Church.

In all Christian communities the Sunday has been observed with more or less strictness, the degrees of which seem to depend on three different views which are held respecting its character. Some regard all the provisions of the fourth commandment as extending to it, admitting however an exception in the case of "works of necessity and mercy;" others agree with these in abstaining from worldly business and amusements, because they think that only thus can the mind be fitted for the religious services which are observed on this day; while others, viewing it as a day of rejoicing, a Christian festival, devote a part of the day to religious worship, and the remainder to recreation. To these views ought to be added a fourth, which, though never adopted, we believe, by any church, has been the opinion of many eminent theologians, namely, that there is no divine authority for making a distinction between Sunday and other days. The whole subject has been fully examined by Dr. Hessey in his 'Bampton Lecture—Sunday, its Origin, History, and Present Obligations,' 1860.

SUNDAY, the first day of the week, a day kept holy by Christians. The common law is silent as to the observance of Sunday, and it seems once to have been the practice not only to exercise worldly callings on that day, but also especially to devote some part of it at least to sports and pastimes, such as now prevail in continental countries, both Protestant and Roman Catholic. This practice continued till some time after the Reformation. Plays are said to have been performed on Sundays at the court of Elizabeth, and even of Charles I. The first restriction that appears among the printed statutes is by the 27 Hen. VI., c. 5, which enacts that all fairs and markets held on Sundays shall cease (the four Sundays in harvest excepted), on pain of the forfeiture of the goods exposed for sale. Immediately after the Reformation in England the legislature regulated the observance of Sunday. The first statute relative to the subject, the 5 & 6 Ed. VI., c. 3, recites that there is not any certain time, or definite number of days, prescribed in Scripture to be kept as holy-days, but the appointment of them is left to the Church, to be assigned in every country by the discretion of the rulers and the ministers thereof. The statute proceeds to enact that certain days mentioned, such as Christmas Day, Good Friday, &c., and all Sundays in the year, shall be kept holy-days; but it provides that in harvest, or any other time when necessity shall require, any kind of work may be done upon those days. No penalty is attached to the infringement of this Act. It is said to have been drawn up under the inspection of Cranmer. By the 1 Eliz., c. 2, all persons having no lawful or reasonable excuse to be absent, are to resort to their accustomed parish church or chapel on Sundays, or to forfeit twelve pence, which was recoverable before justices. The party so offending is also made amenable to ecclesiastical censure, but is only liable to one punishment, be it ecclesiastical or civil. Soon after this time the Puritans and other strict religionists attained political influence. Entertaining a greater predilection for the history and economy of the Jews, as contained in the Old Testament, than had hitherto been exhibited in the Christian world, they began to style Sunday, a term which they thought profane, as derived from Saxon idolatry, the "Sabbath," or "The Lord's Day," names which are not used in the statutes previous to that period. In accordance with this mode of thinking, they seem to have been of opinion that the Christian Sunday ought to be observed in the same manner as the Jewish Sabbath. It was with a view to counteract such opinions, that, in 1618, James I. wrote his 'Book of Sports,' in which he declares that dancing, archery, leaping, vaulting, May-games, Whitsun-ales, and morris-dances were lawful, and that no such honest mirth or recreation should be forbidden to his subjects on Sundays after evening service. The 'Book of Sports' was re-published by Charles I. in 1638. (5 'Harleian Miscellany,' 75.) The Puritans, however, becoming the stronger party, their opinions prevailed, and there followed a rapid succession of enactments in furtherance of them. But the most important statute on the subject is 29 Chas. II., c. 7, which enacts (sect. 1) that no tradesman, artificer, workman, labourer, or other person whatsoever, shall do or exercise any worldly labour or business or work of their ordinary callings on the Lord's day (works of necessity and charity only excepted); and it prohibits the sale and hawking of wares and goods. Sect. 2 prohibits drovers, horse-coursers, waggoners, butchers, higglers, and their servants from travelling, and the use of boats, wherries, lighters, or barges, except on extraordinary occasions. By sect. 3 the dressing of meat in families, the dressing and selling it in inns, cook-shops, or victualling-houses, and crying milk before nine and after four, are excepted from the operation of the Act. By sect. 6 persons are prohibited from serving or executing any process, warrant, &c. (except in cases of treason, felony, or breach of the peace), on the Lord's day: the service, &c., is made void, and the person serving it is made liable to damages, as if he had acted without any writ, &c.

By the 10 & 11 Will. III., c. 24, mackerel are permitted to be sold before and after divine service on Sundays, and forty watermen are allowed to ply between Vauxhall and Limehouse. The 21 Geo. III., c. 49, enacts that no house, &c., shall open for any public entertainment or amusement, or for publicly debating on any subject on Sundays.

The 7 & 8 Geo. III., c. 75, repeals that part of 29 Chas. II. which relates to travelling by water. By 34 Geo. III., c. 61, bakers are enabled, between nine and one o'clock on Sundays, to bake for persons things which are brought to their oven. By 1 & 2 Will. IV., c. 22, drivers of hackney-carriages may ply, and are compellable to drive on Sundays. The 3 Will. IV., c. 19, empowers the court of aldermen, or two justices, to regulate the route of stage-carriages, cattle, &c., on Sundays. These two statutes relate to London only. The 3 & 4 Will. IV., c. 31, provides that the election of corporate officers, &c., required to be held on any particular day, shall take place on Saturdays or Mondays, when the day specified in the Act happens to be a Sunday.

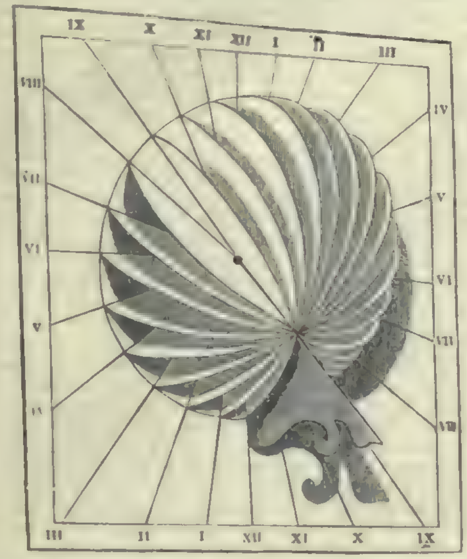
Under these enactments the courts have determined that a contract or sale which, though made on Sunday, is not in the exercise of the ordinary calling of the parties, is valid. Thus a contract of hiring between a farmer and a labourer, and a bill of exchange drawn on a Sunday, have been held to be good. The owner of a stage-coach is not included within the provisions of any of the statutes on the subject; the words "other person whatever," in 29 Chas. II., being restricted in application to persons of the same classes as those enumerated by name. An action, therefore, may be maintained against him for neglecting to take a passenger. Only one offence can be committed by the same party against the provisions of 29 Chas. II., c. 7, by exercising his ordinary calling on a Sunday. Several statutes regulate the hours within which public-houses and other places of refreshment may be kept open on Sunday, the regulation thus made being enforceable by penalties summarily recoverable before magistrates.

SUNDAY SCHOOLS. [SCHOOLS.]

SUNDIAL. Up to a comparatively recent period the science of constructing sundials, under the name of Gnomonics, was an important part of a mathematical course. As long as watches were scarce, and clocks not very common, the dial, which is now only a toy, was in actual use as a timekeeper. Of the mathematical works of the 17th century which are found on book-stalls, none are so common as those on dialling. All that is now necessary is to give some idea of the principles on which such instruments are constructed, as an illustration of a leading fact in astronomy. If a person were to place a staff in the ground, so as to point either vertically or otherwise, and to watch its shadow at the same hour, on different days at some intervals from each other, marking its direction at each day's observation, he would in all probability find that the direction of the shadow, the hour being always the same, varied from day to day. He might, however, find that the shadow was always in one direction at the same hour, and this might happen in two different ways. First, he might by accident fix the staff in a direction parallel to that of the earth's axis, in which case the direction of the shadow would always be the same at the same hour, at all times of the year, and for every hour. Secondly, having fixed the staff in a position not parallel to the axis of the earth, he might happen to choose that particular hour, or interval between two hours, at which the shadow of a staff in *that one direction* always points one way. But if, as is most likely, he were to fix the staff in a direction which is not that of the earth's axis; and if, as is again most likely, he were to choose any time of observation but one, the shadow would certainly point in different directions at different periods.

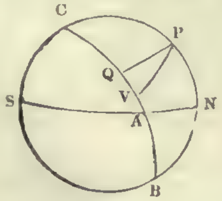
A sundial consists of two parts: the *style*, which is the staff above mentioned, usually supplied to the edge of a plate of metal, always made parallel to the earth's axis, and therefore pointing towards the north; and the dial, which is another plate of metal, horizontal or not, on which are marked the directions of the shadow for the several hours, their halves and quarters, and sometimes smaller subdivisions. In the accompanying diagram, the style is seen throwing its shadow between the directions marked IX and X, on the western side, and indicating that it is about a quarter past nine in the morning. But there is one prominent part of the figure which is never seen on a dial, namely, the hour circles, which are represented as all passing through the edge of the style. As the diagram stands, a skeleton globe of hour circles only is made a part of the construction, to assist in the explanation.

Let us suppose the sun to move with an equable motion, so that it shows the same time as the clock. It does not do so in reality, but the consideration of this point belongs to the article TIME. A large sundial is frequently furnished with a table of the correction of sun-time, to turn it into clock-time, engraved on its face; but this is generally soon corroded. Nor is knowledge of the simplest elements of astronomy so widely diffused as to make such a table of any great use. A person who stations himself in any place of resort which has a sundial, will soon find a lounger who looks in amazement at the difference, perhaps a quarter of an hour, between his watch, which he knows to be right, and the shadow. The church-clock and the sun, in both of which he implicitly believes, are at variance, and he is hardly able to resist the melancholy conclusion that his watch has gained or lost a quarter of an hour in a ten minutes' walk. Neglecting the cause of this, which is an irregularity of solar time, and has nothing to do with any particular mode of reading the results, let us suppose that it is nine o'clock in the morning, solar time. This means that the sun is in that hour-circle which belongs to three hours before noon, or is 3 × 15 or 45 degrees from the meridian hour-circle towards the east. The meridian hour circle is that which cuts the plate of the dial in the line XII XII; and the hour-circle in question (the right-hand one of the two which are not shaded) cuts the dial-plate in IX IX. Now when the sun is in the continuation of any plane, the shadow of that plane is only that of the edge presented to the sun. The upper edge of the style is common to all the hour-circles; and its shadow is, therefore, for the time, part of that of the hour-circle in which the sun is. Hence at nine o'clock before noon the line O IX will be the shadow of the style, O being at the intersection of the edge of the style and the dial-plate (marked by a large dot in the figure). In the diagram, the day has moved on about a quarter of an hour after the time just described, and the shadow has advanced accordingly. There is in it a trifling error of shading (it was taken from De Parcieux's 'Trigonometry,' a work which is very rich in well-drawn solid figures), which will serve to illustrate the subject. The time being between nine and ten o'clock, the sun ought to be looking directly into the crevice between the hour-circles IX and X, in which crevice there ought therefore to be no shadow; but the crevice which is entirely devoid of shadow is that between the hour-circles VIII and IX, so that the sun is made to tell one story on the north side, and another on the south, of the figure. The reader will easily set this right, and will see that as far as the whole hours are concerned, the crevices themselves might be made to answer the purpose of a sundial.



Though the preceding figure was drawn for a horizontal dial, yet any other plane might be substituted. The objections to a dial are, that the shadow of the style is not sufficiently well defined to give very accurate results, even for ordinary purposes: that refraction, which always makes the sun appear a little too high, throws the shadow a trifle towards noon at all times, that is, makes the time too fast in the morning, and too slow in the evening; and that a correction is always necessary in order to find mean or civil time. Even if the first objection could be got over, the corrections requisite for the two latter would prevent persons in general from making use of the instrument. If the edge of the style be not very narrow, it is necessary to have the morning and evening halves of the dial separated by the breadth of that edge.

Those who understand spherical trigonometry will easily see that the general problem of a sundial consists in that of finding out where the hour-lines cut a given circle, as follows. Let BQC be the circle in which the plane of the dial produced cuts the heavens, and let the angle CAS, which it makes with the horizon (h), and CBN, which it makes with the meridian (m), be given. From P, the pole, draw QP perpendicular to the plane of the dial; and the line joining P with the centre being the continuation of the style, that joining the centre with Q is the continuation of what is called the *substyle*. Now in the right-angled triangle ANB, we have



$$\cos \mathrm{NB} = \frac{\cos h}{\sin m},$$

whence NB is found; to which add the latitude of the place, PN, and PB is found. The equations

$$\tan \mathrm{PB} \,.\, \cos m = \tan \mathrm{QB}, \quad \sin \mathrm{PB} \,.\, \sin m = \sin \mathrm{PQ}$$

show how to place the substyle with respect to B, the point answering to noon; and also how to place the style with respect to the substyle. To find the point V at which any given hour-line, PV, cuts the circle CB, first find the angle QPB from

$$\cot \mathrm{QPB} = \tan m \,.\, \cos \mathrm{PB};$$

and VPB, the hour-angle from noon of the sun (V being a point in the shadow). The difference of these angles, QPV, or their sum, is then known; and QV is found from

$$\tan \mathrm{QV} = \tan \mathrm{QPV} \,.\, \sin \mathrm{PQ}$$

It will be better for the beginner to verify these steps on a correctly drawn figure, or to modify them, than to make purely algebraical alterations. Also it is to be remembered that the position of the dial may require both sides of it to be graduated, and the style to extend in both directions, to suit all times of the year and all hours of the day.

SUNNAH. This is the name given by the Mohammedans to the traditionary portion of their law; which was not, like the Korán, committed to writing by Mohammed, but preserved from his lips by his immediate disciples, or founded on the authority of his actions. It holds in Mohammedan theology the same place as the Mishna in the Jewish doctrine, and the names agree in their derivation. The orthodox Mahommedans called themselves Sunnites, in distinction to the various sects which are comprehended under the term Shiites, whose distinguishing characteristic is that they recognise as lawful kalifs Ali and his descendants. The Turks as a nation are Sunnites, and the Persians Shiites. Shiah, from which this latter name is derived, signifies a party or troop.

SUPERCARGO. [SHIPPING, SHIPS.]

SUPERFICIES, the Latin form of the word surface, used in the sense of surface, and sometimes of area. The quantity of an area is called its superficial content, as distinguished from linear content or length, and solid content or bulk.

SUPERPHOSPHATE OF LIME. [CALCIUM, *Superphosphate of Lime.*]

SUPERSEDEAS, in law, the name of a writ used for the purpose of superseding proceedings in an action. In its more general sense it is used to express that which supersedes legal proceedings, although no writ of supersedeas may have been used for that purpose. Thus if a writ of certiorari be delivered to an inferior court for the purpose of removing a record to a superior court, the writ of certiorari is said to be a supersedeas of the proceedings before the inferior court.

SUPPLEMENT (Trigonometry). The defect of an angle from two right angles. Also chords or arcs of a circle or other curve which have a common extremity, and together subtend an angle of two right angles at the centre, are sometimes called supplemental chords or arcs.

SUPPLY. [PARLIAMENT.]

SUPPURATION. [ABSCESS; INFLAMMATION.]

SUPRALAPSARIANS. In the discussions of the doctrines of predestination and election, which arose out of the teaching of the school of theologians at Geneva, two different views came to be taken by the Calvinistic party. Some held that all the occurrences which take place on the earth have been from eternity the subject of a special decree of God: that God decreed to create man solely for his own glory, and to display his glory in the eternal happiness of some and the damnation of others: that this decree respected not merely the end, but all the means, direct or indirect, by which that end was to be wrought out; and that sin, the fall of man, and the introduction of evil into the world, were decreed by God to happen as necessary means to the end proposed, and God therefore so constituted man, and placed him in such circumstances, that he could not but fall. The persons who held these views were called *Supralapsarians* (*supra lapsum*), because, according to their system, the decrees of God respecting the salvation of some men and the rejection of others were in no sense consequent or dependent upon the foreseen fall of man, which itself (on the contrary) took place in consequence of a divine decree.

The other party were called *Infralapsarians.* They considered the decrees of God for fixing the eternal state of man as equally eternal and unchangeable, but they maintained that God did not create man in order that he might fall, but left him free to act for himself; and, though foreseeing that he would fall, did not interfere to prevent him, but decreed that the consequences of this foreseen fall should result in increased glory to himself, and the eternal happiness of the greater part of men.

The synod of Dort adopted the views of the Infralapsarians. Modern Calvinists, generally, go no farther than Infralapsarianism, and often not so far.

SUPREMACY is a term used to designate supreme ecclesiastical authority; and is either papal or regal. Papal supremacy is the authority, legislative, judicial, and executive, exercised until nearly the middle of the 16th century by the pope over the churches of England, Scotland, and Ireland, as branches and integral parts of the Western or Latin church, and which continues to be exercised *de facto* over that portion of the inhabitants of those countries who are in communion with the church of Rome. The extent of the legislative authority of the pope was never exactly defined. Whilst it was regarded as nearly absolute at Rome and at Madrid, it was, at Venice, and still more at Paris, sought to be reduced within very narrow limits.

The papal supremacy was abolished by the legislatures of the three kingdoms in the 16th century. In order to ensure acquiescence in that abolition, particularly on the part of persons holding offices in England and Ireland, an oath has been required to be taken, which is generally called the oath of supremacy, a designation calculated to mislead, it being in fact an oath of *non*-supremacy rather than of supremacy; since, though in its second branch it negatives the supremacy of the pope, it is silent as to any supremacy in the crown. This oath was therefore taken without scruple by persons who were not Roman Catholics, whether members of the Anglican church or not. Roman Catholics might take an oath in which the *civil* and *temporal* authority of the pope were abjured. By the 21 & 22 Vict. c. 48 (1858), the oath was abolished, and another substituted which only pledges the person taking it to temporal allegiance to the sovereign, and repudiates the jurisdiction of any foreign power, spiritual or temporal, of whatever nature it may be.

Regal supremacy is not legislative, but judicial and executive only. Henry VIII. was first acknowledged as supreme head of the church by the clergy in 1528. This supremacy was confirmed by parliament in 1534, when, by the statute of 26 Henry VIII., c. i., it was enacted that "the king our sovereign lord, his heirs and successors, kings of this realm, shall be taken, accepted, and reputed the only supreme head in earth of the Church of England, and shall have and enjoy, annexed to the imperial crown of this realm, as well the style and title thereof, as all honours, dignities, pre-eminencies, jurisdictions, privileges, authorities, immunities, profits, and commodities to the said dignity of supreme head of the same church belonging and appertaining; and shall have power from time to time to visit, repress, redress, reform, order, correct, restrain, and amend all such errors, heresies, abuses, offences, contempts, and enormities, whatsoever they be, which, by any manner of spiritual authority or jurisdiction, may lawfully be reformed, repressed, ordered, redressed, corrected, restrained, or amended, most to the pleasure of Almighty God, the increase of virtue in Christ's religion, and for the conservation of the peace, unity, and tranquillity of this realm; any usage, custom, foreign laws, foreign authority, prescription, or any other thing to the contrary notwithstanding."

SURD. This word has been used to signify an IRRATIONAL arithmetical or algebraical quantity since the time of the introduction of algebra into Europe; though why any term formed from *surdus* was used in such a sense is not known; perphaps it was the supposed translation of an Arabic term. In the article just cited we have said as much as is necessary on the subject. We will only add that the second volume of Cossali's 'History of Algebra' contains an account of the tenth book of Euclid, with reference to the use made of it by the earlier algebraists.

SURDITES. [DEAFNESS.]

SURETY. A surety is one who undertakes to be answerable for another, who is called his principal. Such undertaking must be in writing, and it may be either by bond or by simple writing. A contract is not binding in law, unless made upon some sufficient consideration; but in the case of a bond this consideration is inferred from the circumstances of deliberation incident to its execution as a deed. When the undertaking is not by bond, it is necessary that the consideration should be capable of proof, and that the instrument should be signed by the party who becomes the surety. The instrument however may consist of several writings, if they are so connected by reference to each other that they can be considered as incorporated. The instrument by which the surety becomes bound, when it has reference to civil matters, is generally called a guarantee, and ordinarily consists of an undertaking to become answerable for the payment of goods furnished to the principal, or for his integrity, skill, attention, and other like matters. In such cases the consideration would probably be the furnishing of the goods to the principal, or his employment by the party guaranteed. In the construction of guarantees the same rule of law prevails as in the case of all written instruments,—that they shall be understood in the sense most unfavourable to the party making them which the words will reasonably bear. The application of the rule is very frequent in cases of guarantee where the question arises whether or not the guarantee is what is called a continuing guarantee. Thus where the surety undertakes to be answerable to the amount of 100*l.* for goods supplied to his principal, this may mean that he will be answerable for the first 100*l.* worth, and cease to be answerable for any goods supplied afterwards; or, that he will continue to be answerable to the amount of 100*l.* for any indefinite period during which goods may be supplied, although the principal has paid for the first 100*l.* worth. The latter kind of guarantee is called a continuing guarantee. Observations of a similar character may be made as to the application of payments by the principal.

The circumstances connected with the relative position of the guaranteed and the principal are considered as embodied in the contract between the guaranteed and the surety, and as forming part of that upon which the undertaking of the latter is founded. If, therefore, these are substantially varied, so as to increase the risk of the guaranteed, or to destroy or suspend his remedy against the principal, the surety is thereby discharged. Thus, if the guaranteed has, at the time the guarantee is given, a lien upon property of the principal in his hands, which he afterwards parts with; or if he extends the time of credit, or after commencing an action against the principal gives him time, the surety will be released. But the variation of circumstances must be substantial; a change which does not operate so as to increase the risk or lessen the remedy will not have such an effect. Neither can the surety discharge himself by a mere request or caution to the guaranteed to abstain from trusting the principal, or to watch his acts, &c. Nevertheless it is the duty, and perhaps an implied undertaking, on the part of the guaranteed, against the consequences of the neglect of which a court of equity might relieve the surety, to employ a reasonable degree of prudence and attention in intrusting his goods, or inspecting and checking the accounts of his clerks or servants. The surety is entitled to the benefit of all the securities which the guaranteed has against the principal.

With respect to the rights of the surety against the principal, Mr. Justice Buller has distinctly laid down the law, "wherever a person gives a security by way of indemnity for another, and pays the money, the law raises an assumpsit," that is, implies a promise on the part of the principal to repay to the surety all the money that he has expended on his behalf, and this money may be recovered in an action against the principal for money paid to his use. But in no case is the surety entitled to more than an indemnity from his principal. Thus, if the guaranteed is content with a less sum from the surety, instead of exacting the full amount for which he is liable, the principal will be bound to repay to the surety the less sum only. If the surety has himself taken a bond or other security from the principal, he relinquishes his right to bring an action upon the promise implied in law, and must have recourse to an action upon his security.

Where more persons than one become sureties for the same principal, they are called co-sureties. If one of these has paid the whole of the debt due from the principal, he may recover in an action of assumpsit from his co-sureties the amounts for which they were respectively liable. A court of equity will also interfere to regulate the proportions partly due from each. And in case any of them are unable to pay from insolvency, &c., it will compel the others to contribute proportionally the amount for which the defaulters were liable. The law is the same as to co-sureties, whether all have been created by the same instrument in writing, or each one by a distinct instrument.

SURETY OF THE PEACE is the acknowledging of a recognisance or bond to the crown, taken by a competent court for keeping the peace. Magistrates have the power to take such recognisances, which are generally done by the party acknowledging (*recognising*, and hence the term *recognisance*) that he is indebted to the crown to a certain amount, the condition of which bond is, that he or the party for whom he becomes bound shall keep the peace during a term named in the condition. Such recognisance may be obtained by any party from another on application to a magistrate, and stating on oath that he has just cause to fear that such other "will burn his house, or do him a corporal hurt, as by killing or beating him, or that he will procure others to do him such mischief." Upon such application being made to the magistrate, it is his duty to summon the party before him and cause him to enter, either alone or with others, into such recognisances as he thinks the case demands. The fear must be of a present or future danger: no recognisances are demandable on the ground of a past offence. Upon the neglect or refusal of the party so summoned to enter into the recognisances demanded, he may be committed to prison by the magistrate for a specified period, unless he sooner complies. If the recognisance is forfeited by a breach of the condition, it may be removed into one of the superior courts and there proceeded upon.

Sureties also may be similarly required for the good behaviour of parties who have been guilty of conduct tending to a breach of the peace, abusing those in the administration of justice, &c.

SURFACE, SURFACES, THEORY OF. For the mere definition of surface, see SOLID, &c. We are here to speak of that branch of algebraic geometry which considers the generation and properties of curve surfaces following an assigned law.

If three planes, each at right angles to the other two, be taken as the planes of CO-ORDINATES, the position of any point is determined so soon as its co-ordinates, or distances from the three planes, are given in sign and magnitude. If the co-ordinates of a point be x, y, z, and if between these one equation exists, $\phi(x, y, z)=0$, any point may be chosen in the plane of x and y, by means of given values of x and y, and the corresponding value or values of z may be found from the equation. The locus of all the points whose position can be ascertained by determining one of the co-ordinates from this equation, the other two being taken at pleasure, is a surface of which $\phi(x, y, z)=0$ is called the equation, and the modes of proceeding are pointed out in all works on algebraic geometry. The applications of the differential calculus depend on the principles explained in TANGENT: the graphical use of the whole method depends mostly on descriptive geometry, whether formally known under that name or not.

Surfaces are distinguished algebraically by the nature and order of their equations. Thus we have surfaces of the first order, in which the equation is of the first degree (this class contains the plane only); surfaces of the second order, which will be classified in the next article; and so on.

Surfaces are also distinguished by their mode of generation, and some of the principal cases are as follows:—

1. *Cylindrical surfaces* are generated by a straight line infinitely produced in both directions, which moves so as always to be parallel to a given line, and to have one of its points on a given curve.

2. *Conical surfaces* are generated by a straight line infinitely produced in both directions, which always passes through a given point or vertex, and has one point in a given curve. The common CYLINDER and CONE would be described in this science as a *right circular cylinder* and a *right circular cone*. The cylindrical surfaces themselves are only an extreme case of the conical ones, being what the latter become when the vertex is removed to an infinite distance.

2. *Surfaces of revolution* are generated by the rotation of a curve about an axis, relatively to which it always retains one position. The common cone and cylinder, the SPHERE, and others of the greatest practical use, are contained in this class.

4. *Tubular surfaces* are generated by a circle of given radius, which moves with its centre on a given curve, and its plane at right angles to the tangent of that curve. When the given curve is a circle, the tubular surface is a common ring.

5. *Ruled surfaces* (the *surfaces réglées* of the French writers) are those which are described by the motion of a straight line, which neither remains parallel to a given line nor always passes through a given point. This includes, among many others, the whole class of *conoidal surfaces*, made by a straight line which moves parallel to a given plane, and always passes through a straight line perpendicular to that plane, and also through a given curve. The surface of a spiral staircase, as it would be if there were no steps but only a gradual ascent, is an instance.

6. *Developable surfaces* are those which can be unwrapped on a plane without any doubling of parts over one another, or separation; that is, without being rumpled or torn. The only familiar instances are the cylinder and cone.

SURFACE OF ELECTRICTY. [POLARIZATION OF LIGHT.]

SURFACE OF THE EARTH. Geology, by teaching us to look upon the form and distribution of land and sea, the features of hills and valleys, and the various deposits of peat, silt, gravel, &c., as effects of physical agencies, some of which are no longer in operation upon those areas where once they predominated, confers upon the surface of the earth an interest much greater than that which belongs merely to pictorial combinations, or even to agricultural utility and commercial adaptation. Uniformity, inequality, height, depth, and area, every the least peculiarity of form, whatever is remarkable in any part of the surface of the land or bed of the sea—these are effects of causes which require to be traced out before the problem of the physical history of the globe can be considered as resolved. Geology was pronounced by Sir C. Lyell, early in his career of research, to be the science of surfaces.

Superficial Deposits. If the stratified and unstratified rocks which compose the skeleton of the earth were laid bare to our view, the aspect of the globe would be far more rugged than it is now. The valleys would in many cases lose their soft and easy curvatures and accordant slopes, in angular fractures and irregular chasms; the mountains and hills would lose those sloping buttress-like banks, composed of fallen materials, which connect the broken ridges above with the level expanse below; a sterner aspect would belong to the now sinuous lines of sea-coast; and an almost general barrenness would overspread the inland surface.

The soil, gravel, clay peat, and other substances, which by their accumulation mask the features of the interior rocks, constitute a peculiar class of phenomena which have been much, and yet not sufficiently, studied by geologists. It is certain that without a more exact appreciation of the causes which have permitted the aggregation of the "superficial deposits" already named, our analysis of the processes whereby the earth has been made fit for the residence of man, and adapted to its present uses, must be very imperfect.

Soil is often supposed to be merely the disintegrated parts of the subjacent rocks, and this is sometimes really the case; trap rocks, for example, of which the felspar and the hornblende become decomposed by the atmosphere, yield a soil often remarkable for fertility, and uncontaminated with foreign ingredients. But the soils which cover clays and limestones and sandstones are seldom of this simple origin. The bases of these soils may be generally derived from the subjacent strata, but they usually contain foreign ingredients. The soil on the chalk and limestone hills of England is often sandy, sandstones are covered by loam, and clays overspread with pebbles. The effect of this admixture of foreign substances with the disintegrated parts of the native rock is usually favourable to fertility.

We may often understand the cause of these admixtures by considering the effect of rains and currents of water on the sloping surface of the earth. These effects arrive at a maximum in particular vales and plains, into which many streams enter after flowing over strata of different kinds. In such vales the soil is in fact a mixture of calcareous, argillaceous, and arenaceous parts, and its indigenous plants are correspondingly varied, and include many which are not found growing together on any one of the soils which are here mixed together. [SOIL.]

To watery agency, acting under the actual circumstances of physical geography, we may also ascribe many even extensive accumulations of gravel and sand which lie along the sides of valleys and in hollows of hills, or on the slopes of mountains; and it requires sometimes only the postulate, that in particular valleys inundations have formerly reached higher levels than at present, to apply the same explanation to terraces of gravel and sand now considerably above the actual flood-mark, but sloping parallel to the general inclination of the valley.

The beds of old lakes, often consisting of layers of shelly marl, with bones of existing or extinct quadrupeds, the surfaces of silt which lie along the actual and ancient æstuaries of rivers, and often conceal buried forests and subterranean peat, present no difficulty as to their origin. For the processes by which peat grows and trees are buried, and marshy land is saved from the sea, and lakes are filled up, are at this day in action. To all such peat or turf moors, subterranean forests, marsh and fen land, drained lake-beds, and sand and gravel, the title of *alluvial deposits* is very commonly given. Generally, they require no supposition of extensive changes of physical geography produced by violent disturbances of nature, but seem to be clearly and perfectly explicable by causes still in action, though perhaps not in the same situations on the earth's surface. But there are other gravels, sands, and clays, to which this explanation cannot be applied without calling in aid great changes of physical geography, or physical processes not seen in daily operation; such as extensive displacement and change of level of land and sea; unusual floods of water; surprising alterations of climate, or movement of glaciers in situations where now the snow and ice of the coldest winter melt with the first breath of spring. These phenomena were classed under the title of *diluvial deposits*, at a time when their origin was very generally ascribed to violent floods of water, and the title was retained even by geologists who did not admit this hypothesis. They are now generally included by geologists under the designations of boulder-clay, boulder formation, and northern drift; the latter term having been applied to them, because, in Europe and in North America, where only they have yet been distinctly recognised, they have evidently been brought from regions to the north of those in which they are now found. At the same time, according to Sir C. Lyell, "the bulk of the mass in each locality consists of the ruins of subjacent or neighbouring rocks; so that it is red in a region of red sandstone, white in a chalk country, and gray or black in a district of coal or coal-shale." They belong both to the newer pleiocene or pleistocene and to the post-pleiocene series of present geological nomenclature.

These so-called diluvial deposits are commonly admitted or assumed to be of older date than those called alluvial, and, taken in a collective sense, they are so, but this is the least important circumstance characteristic of their history. The conditions of their accumulations are remarkable.

1. It is often seen that thick deposits of clay, sand, and pebbles, or large fragments of rock, lie on the very summits of hills (as abundantly on the hills which adjoin the valley of the Thames).

2. Fragments of rocks quite unlike those of the vicinity lie in valleys, on hills (as on the Salève near Geneva), and even on islands (as on Staffa).

3. These fragments are found solitary, or buried in clay, sand, or gravel, and sometimes in enormous abundance, as in Huntingdonshire, near Birmingham, in Holderness, and other parts; and they are such that no stones of like nature occur anywhere in the natural drainage of the country where the gravel is accumulated, nor within 20, 50, or even 100 miles of the spot.

4. The fragments (often called boulders, and also erratic blocks) appear thus in several cases to have been transported from particular parts of the country, over elevated ground, across the natural valleys and ranges of hills, but yet are, in some cases, distributed in a manner

which manifests a decided dependence on some of the greater features of physical geography. Thus the abundantly spread detritus from the Cumberland mountains crosses the island to Tynemouth, and reaches the coast of Yorkshire, but does not cross the Pennine chain of mountains, except at one point (Stainmoor), though it spreads along the western side of it as far south as Manchester and the plains of Cheshire and Staffordshire. In like manner the detritus from the Western Alps has been carried on to the Jura, and lies in a strange manner in all parts of the hollow of the Lake of Geneva, and on the insulated Salève Mountains; yet it has been observed that the lines followed by the boulders are those of the great valleys, so that each great valley has been the direction in which were carried the blocks from the head of that valley.

5. It is observed that often the largest blocks contained in a mass of this detritus lie at the top, resting on the smaller gravel and sand; and that below the whole mass the hard rocks are scratched by parallel distinct small grooves or striæ, marks of the dragging movement to which the stones were subject in their passage.

6. Though in some cases successive deposition can be traced in the parts of such a mass, it is very often seen that the materials are entirely unarranged, mere heaps of stones, and sand or mud; the stones being often indiscriminately stuck in clay, large and small, heavy and light, absolutely without any stratification, such as long suspension in water must certainly have produced.

7. Finally, amidst such confused masses, bones of land quadrupeds, mostly or entirely of extinct species, and even of extinct genera, occur, and locally even in abundance. These are, however, more common in laminated lacustrine deposits resting upon the diluvial masses, or perhaps covered by them.

With the mammalian remains alluded to are not unfrequently associated, as has recently (1861) been shown, flint implements of human work; indicating, if not proving, the contemporaneity of some of the now and long since extinct mammals with certain races of man. (Prestwich, in 'Phil. Trans.,' 1860.)

It was thought possible to explain these characteristic phenomena by many local inundations, or one general and overwhelming flood, capable of overcoming many of the lesser inequalities of surface-level, but modified in its course by the larger ranges of mountains and valleys. And as in the northern zones of the world (which have been much investigated in this respect) there is a very frequently observed direction of the boulders to the south or south-east, it has been proposed for consideration whether some great change of the level of land and sea in the circumpolar regions might account for what seems a general fact. But further, as the most abundant deposits of this nature have been drifted from particular chains of mountains, as the Cumbrian group in England, the primary mountains of Norway, the Alps, &c., all which districts have undergone elevation *at some time*, it has been thought that their upward movement may have been the cause of the displacement and transport of the blocks. (Buckland, 'Reliquiæ Diluvianæ;' Elie de Beaumont, 'Sur les Revolutions du Globe.')

It has, however, been proposed to account for the distribution of the boulders by a more gradual action of the waters of the sea. If the region of Cumbrian rocks, for example, and a very large portion of the north of England, were supposed to be raised from the sea, by a continual or intermitting movement, so as to bring successively under the action of the breakers the whole country to the east and south-east of the area now occupied by the Cumberland mountains, this would allow of a continual drifting of the boulders to the east and south, by the continual tendency of the tides and currents of the sea. (Phillips, in 'Treatise on Geology, &c.;' Whewell in Murchison's 'Silurian System.') Floating ice has been represented as adequate to carry off from the shore where it was formed masses of mud and fragments of rocks, and, by melting or turning over, to spread them on the bed of the sea. This sea-bed raised would show the accumulations from such icebergs, often in narrow bands or insulated patches, such as really occur, and have been long celebrated, among the heaps of Norwegian detritus which lie on the sandy plains of North Germany. (Lyell, 'Principles of Geology,' 'Manual of Elementary Geology;' Murchison, 'Silurian System.')

Finally, ice in another form has been appealed to for the explanation of these phenomena. The formation of glaciers in mountain valleys is such as to permit of their forward movement down a slope, and their carrying with them in their progress fragments of rocks and heaps of gravel and mud which by any cause fall upon their surface. These heaps of "moraine" accumulate along the sides and at the lower termination of the glacier, and the arrangement, or rather confused aggregation, of the materials in them resembles very much that of the masses to be accounted for. The surface of the rocks below a glacier is scratched, as we have before stated to happen in places where boulders are noticed; and as in the Alps it is certain that glaciers have formerly been extended much farther from the mountain-summits than now they are [Snow, Perennial], it has been conjectured that anciently, in the times coincident with or preceding the boulder or drift period, they were very much more extended, so as even to have reached from the Alps to the Jura, from the mountains of Norway to those of Bohemia, and from Shap Fells in Westmoreland to the mouth of the Humber. Upon the subsequent contraction of these glaciers, the moraines they had left would experience some changes by the action of water (melted ice), which might then run in lines impossible for watery currents after the ice was fully removed. (Agassiz, 'Etudes sur les Glaciers.') On the grooves and striæ on the surfaces of rocks Mr. Jukes remarks ('Popular Physical Geology,' p. 280), in considering the former action of ice, here alluded to, "In addition to ice however, Mr. Mallet has acutely pointed out that many of these appearances may be due to what he somewhat inappropriately terms 'mud glaciers,' by which he means the sliding forward or slipping of great masses of clay, mud, or sand, charged with pebbles and boulders, along the inland surfaces of rock, either as the land rose from the sea, or when they were subsequently loosened by the action of rain and other water."

The examination of the boulders of certain parts of the Himalayan range, and the application of the theory of glacier movement to explain their distribution, has led Dr. Joseph D. Hooker to suggest some modifications of that theory in respect of those localities. The banks of the Great Rungeet river, near its junction with the Kulhait, consist of mica-slate, cumbered, in a deep gorge through which the river flows, with enormous boulders of that rock, of clay-slate, and of granite, some fully 10 feet in diameter. But the latter rock is not common at elevations below 10,000 feet, whereas the absolute elevation of the river here is only 1840 feet; it is not easy therefore to account for their present position. "They have been transported," Dr. Hooker infers, "from a considerable distance in the interior of the lofty valley to the north, and have descended not less than 8000 feet, and travelled fully fifteen miles in a straight line, or perhaps forty along the river bed. It may be supposed that moraines have transported them to 8000 feet (the lowest limit of apparent moraines), and the power of river water carried them further; if so, the rivers must have been of much greater volume formerly than they are now." Another explanation was required by the enormous fractured boulders of gneiss frequent over the whole of the mountain Mons Lepcha, in the Sikkim Himalaya, at elevations of from 7000 to 11,000 feet. Contrary to those mentioned above, they were of the same material as the rock *in situ*, and as unaccountable in their origin, by received theory, as the loose blocks on the Dorjiling and Sinchul spurs to the south, at similar altitudes, often cresting narrow ridges. Dr. Hooker measured one angular detached block, 40 feet high, resting on a steep narrow shoulder of the spur, in a position to which it was impossible it could have rolled; "and it is equally difficult to suppose," he observes, "that glacial [glacier] ice deposited it 4000 feet above the bottom of the gorge, except we conclude the valley to have been filled with ice to that depth." A third modification of or addition to the glacier theory of boulder distribution, is pointed to by the locality of the Jongri spur of the great mountain Kinchinjunga [Orology], over which are scattered blocks of gneiss, many 20 feet in diameter. "It is not possible to account for the transport and deposit of these boulders by glaciers of the ordinary form, namely, by a stream of ice following the course of a valley; and we are forced to speculate upon the possibility of ice having capped the whole spur, and moved downwards, transporting blocks from the prominences on various parts of the spur." 'Himalayan Journals,' vol. i., pp. 242, 253, 288.

The entire subject of the transport of erratic blocks, and of the hypotheses which have been framed to account for it, has been critically examined by Mr. W. Hopkins, in a paper 'On the Elevation and Denudation of the District of the Lakes of Cumberland and Westmoreland,' in the 'Quart. Journ. of the Geol. Soc.,' vol. iv.

The great mass of diluvium from the Cumbrian mountains, already alluded to, which covers the surface of Lancashire, rests on nothing more recent than the new red sandstone, and Mr. Hopkins conceives that its transport might have begun with the elevatory movements which disturbed that formation, when the surface of the present mountainous district began to rise permanently above the surface of the ocean, and the valleys began to be formed. The spreading out of diluvial matter—that term being now adopted in its broad physical sense—may be regarded as the necessary consequence of wide general currents, and that this has been the agency by which the mass of diluvium in question has been transported to its present locality and position, does not admit, in Mr. Hopkins's opinion, of the smallest doubt. He accounts for the existence of currents diverging from the centre of the district by a repetition of paroxysmal elevations of from 100 to 200 feet; and, affirming the entire adequacy of this cause to transport all the erratic blocks derived from that region, concludes that such has been the agency by which that transport has actually been effected. He rejects the iceberg theory in its application to the case investigated, but conceives that floating ice may probably have been the most efficient agent in transporting the larger blocks of colder regions from their original localities. Mr. Hopkins's paper may be studied with great advantage with reference to the whole subject of the distribution of boulders and of the northern drift.

We do not propose to investigate any of the hypotheses above stated, preceding the facts and reasoning we have derived from Dr. Hooker and Mr. Hopkins. Geologists have been remarkable for eagerly adopting and as easily abandoning most of them; and others might have been added merely as beacons to be avoided. It may be proper however to point out three things which may be useful to remember in further prosecuting this subject, and which, indeed, have neither been forgotten nor neglected, by the geologist last named.

1. It must be determined by evidence whether the accumulation to be explained happened on the land at its present level, or on the bed of the sea.

2. It must be determined by evidence what was the probable character of the climate in the countries where diluvial accumulations excite attention.

3. In proposing a general cause, such for example as the movement of glaciers, it must be shown to be adequate to satisfy all the minuter details of the phenomena, and not inconsistent with general limiting conditions established by extensive induction from facts observed in the earth itself, or admitted as parts of general cosmical theory. [REFRIGERATION OF THE GLOBE; and, in NAT. HIST. DIV., GEOLOGY and SUBMARINE FORESTS.]

The determination of the cause of the diluvial accumulations is of the highest importance in geological theory. It is impossible to doubt that to the same cause must be ascribed many considerable modifications of the *pre-existent surface* of the land. If, abstracting our attention from the accumulated deposits which conceal the stratified and other rocky masses in the crust of the earth, we look at the *actual form* of its surface, there appears little that is even difficult of explanation by the application of known and real causes. The relative areas of sea and land; the peculiarities of outline of continents and islands; the directions of mountain-ranges, and remarkable vales and plains; the individual features of hills and valleys; the degree in which the land is wasted in some quarters and augmented in others; and the rate of change which may take place in these respects;—all this may be satisfactorily referred to subterranean and submarine disturbances of different periods, to the effects of the sea upon the land when the land was not at its present level above the water, and to the operation of the atmosphere, rains, rivers, and inundations.

From this large field of research we shall select for brief illustration the outlines of land and sea, the directions of high and low ground, and the individual features of hills and valleys. The few examples needed will be drawn from the British Isles, but the explanations are of general application. To render the article, as reproduced in this work, more accordant with the actual state of geology, illustrations of other parts of the subject are now added, some from foreign countries, but of general application equally with the former.

Much of the irregularity of outline, on a large scale, of the British Islands depends on the *form* in which the ancient bed of the sea was elevated into dry land. Thus the line of the Hebrides, the prominent parts of Caithness, of Aberdeenshire, and of Argyleshire, are on axes of upward movement of the primary strata; while the Great Caledonian Valley, from Fort William to Inverness, and the great basin of the Forth and Clyde, are in axes of depression of the strata. This latter hollow is margined on the south by the great axis of elevation of the Galloway and Lammermuir hills, reappearing beyond the Irish Channel south of Belfast, as the Argyleshire chain is resumed in Donegal. The Isle of Man, the promontory of Lleyn in Caernarvonshire, the east and west ridges and hollows of the strata which reach the sea in South Wales and North Devon, give to Pembrokeshire, Glamorganshire, and North Devon remarkable and detailed alternations of promontory and bay. The Isle of Wight is formed on an axis of elevation from the Needles to Culver Cliff; while north of it are the axis of depression of the Solent, the axis of elevation of the wealds of Sussex, and the axis of depression of the estuary of the Thames.

Inland, the same ridges and hollows, and others of as great importance, produce continuous chains of hills, the North-Western Highlands, the Grampians, the Lammermuir range of hills, the Wicklow mountains, the Snowdon mountains, the Berwyn, and Malvern hills, and multitudes of other narrow tracts of elevated land. Great *faults*, elevating or depressing one portion of a natural district, leave marks of inequality on the surface. Thus the great Pennine faults, ranging from Newcastle to Brampton, and thence to Kirby Lonsdale and Settle, occasion differences of level in the ground of 1000 and 2000 feet for a length of 100 miles.

In all cases, and in every country, it appears that, notwithstanding the operation of later agencies, the main features of the surface of the land are due to the positions in which subterranean movements left the displaced masses of rocks. But the operation of subsequent agencies is distinctly traceable in modifications of these features on the sea-coast, and in the interior of every country.

The surface of the land has been *wasted*, and as the various stony and earthy masses which come to the surface have unequal compactness, and are unequally capable of resisting the chemical and mechanical agencies which originate in the varying heat and moisture of the atmosphere, we find in consequence a multitude of irregularities, both on a large and small scale, directly related to the properties of the rocks. On the sea coast some parts are known to be wasted (as the coasts of Sheppey, Dunwich, and Bridlington) even rapidly, one or several yards annually on the average; others seem almost unchanged by a thousand years of storm and tempest, as the "Worm's Head;" and some considerable tracts of new land have been added to the shores of Lincolnshire, along the banks of the Thames, and by the side of the Severn.

The line of coast from the Tyne to the Humber is instructive in this respect. The prominences on the Durham coast, ending with Hartlepool, are guarded by magnesian limestone, and the estuary of the Tees is excavated in red marl and lias clays. The peak near Robin Hood's Bay, Scarborough Castle Hill, Filey Brig, and Flamborough Head, are all promontories of hard rocks; but Robin Hood's Bay, Scarborough Bay, Filey Bay, and Bridlington Bay, are all excavated and wasted in clays of the liassic, oolitic, and diluvial periods. The interior of the country shows similar effects on a grander scale. The great vales and plains of England, in parts the least influenced by subterranean disturbances, are by no means the excavated paths of rivers, nor are the great ranges of hills the separating summits between such rivers. The plains and vales are lines of soft and perishable strata, and the crests which divide these vales are ranges of harder rocks. A transverse section of the English strata shows always, both on a large and small scale, this important fact (see *fig.* 1), and every well-shaded topographical map, coloured geologically, demonstrates the extent of its application in explaining the irregularity of surface. The chalk hills, oolitic hills, &c., alternating with vales of clay, in all the southern and eastern parts of England, give to those parts characters far more important than the undulations connected with river channels.

Fig. 1.

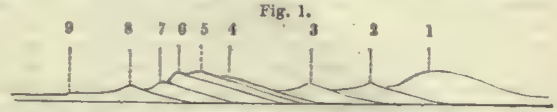


Fig. 1 shows the relatively prominent parts in a line of section across the secondary strata. 1, being chalk; 2, lower green-sand; 3, coralline oolite and calcareous grit; 4, cornbrash; 5, forest marble; 6, great oolite; 7, inferior oolite; 8, marlstone; 9, lias limestone. The intervening hollows are uniformly argillaceous.

Similarly, hills and valleys, in which rocks of unequal power of resisting watery action appear, show the force and continuity of this action by the prominence of the hard rocks and the excavated surfaces of the softer masses. Thus, in *fig.* 2, we see on the breast and edges of a hill composed of limestones, sandstones, and shales, the especial prominence of the limestones; and where these cross a valley, each limestone edge is the place of a waterfall. By studying in such valleys the manner in which the actual stream wastes the rocks, we can easily assure ourselves of the truth of the general explanation offered above. In *fig.* 3 is a section of a waterfall, showing the edge of limestone (*a*) over which the water falls, and under it a bed of sandstone (*b*) little wasted, but at the bottom a body of shale which has perished by the dampness and spray, and is excavated in a remarkable manner.

Fig. 2.

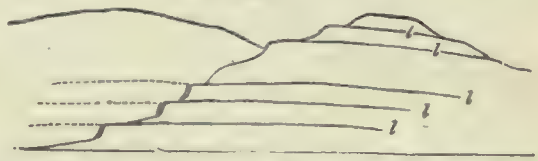


Fig. 2. Aspect of a mountain consisting of carboniferous limestone, shale, and sandstone; the limestone bands (marked *l*) project remarkably, and, where they cross a valley, make waterfalls.

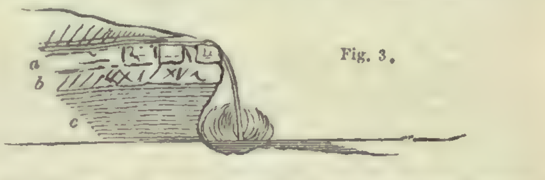


Fig. 3.

Fig. 3. The side view of a waterfall, where the stream falls free of the rock, and causes excavation in the subjacent shales.

Just such an action is observable on similar cliffs by the sea, and in each case the same effect follows: the falling of the hard rock at top from want of support below. Thus the situation of a waterfall is daily displaced, and is moving up the stream, as the Falls of Niagara and Hardrow Force are known to have done. (Lyell, 'Principles of Geology.') Into all these effects of waste on the earth's surface rain enters for something important. Few surfaces of rock are altogether exempt from chemical changes dependent on atmospheric variations; all are more or less liable to perish with rain, frost, and watery movements; and thus the individual features of hills and valleys, the ranges of high and low ground, and the outlines of land and sea, appear to be effects impressed by subterranean movements and fractures of the earth's crust, modified by the action of the sea on materials of unequal resisting power, while they were below, and while they were rising through its waters, and by the subsequent mechanical agencies of rivers, rains, and chemical forces excited by atmospheric variations. [GEOLOGY, in NAT. HIST. DIV.]

Mr. G. Poulett Scrope, M.P., F.R.S., the author of some precious contributions to igneous geology, of the most original kind, but which, after the lapse of more than the third part of a century, are only beginning to be duly appreciated, has urged, in his 'Geology and Volcanos of Central France,' first published in 1826, and in a paper on the excavation of certain valleys, communicated to the Geological Society a few years after, the conclusive nature of the evidence of the immense changes in the surface of the earth which have been effected by the action of "meteoric agents"—that is, of the atmosphere, its depositions, and its ever-varying temperature,—together with that of the streams they produce, upon the different rocks and materials constituting the land, and which, in his judgment, entirely supersede the necessity for referring them to the agency of mighty overwhelming floods and currents, however occasioned. Describing the volcanic formations of the Velay, and in particular the position and actual state of a current of lava, which has spread itself to the width of five, seven, and nine miles, covering an extensive and elevated table-land formerly called the Coiron, which consists of Jurassic or oolitic strata, he shows that there cannot be the least doubt but that the whole of this lofty tract of secondary strata has been solely preserved from destruction by its volcanic capping. The remainder of the oolitic formation around, forming the secondary district of the Rhône valley, has been eaten into in all directions by various mountain torrents, and gnawed down by meteoric abrasion to a far lower level. The immense quantity of matter which must have been thus abstracted from the oolitic mass since the epoch at which this lava was emitted from the now extinct volcano of the Mont Mezen—an epoch proved to be but recent by the fact that, beneath the basalt which it has become, a vegetable soil is found, containing terrestrial shells of a species still existing in the same country—"cannot but strike us with astonishment. There can be no doubt," Mr. Scrope continues, "that the surface on which the basalt of the Coiron rests was at that period the lowest of the neighbouring levels, or these repeated currents of liquid [flowing] matter could not have flowed in its direction; yet at present this same surface vastly overtops every other height of the same formation, and ranges upwards of a thousand feet above the average level of the valley-basins of the Ardêche and Rhône on either side. That a considerable proportion of these was excavated by 'rain and rivers,'—in other words, by meteoric agency such as is still in operation, and not by any diluvial or general flood,—is susceptible of direct proof. To attribute, therefore, the remainder to any other cause of an hypothetical nature unsupported by evidence, would seem to be contrary to the rules of analogy. But the conclusion that the greater portion of the valley of the Rhône has been so recently excavated, and by such agency alone, involves important consequences, since the same agents must have been at work everywhere else, and produced results as stupendous during the same comparatively recent period." ('G. & V. of Central France,' ch. viii.) In the second edition of this work, published in 1858 (ch. ix., pp. 207-208, note), the author expresses his opinion that neither Sir C. Lyell (the most comprehensive advocate for the sufficiency of existing causes) nor the bulk of geologists are "even yet sufficiently impressed with the immense amount of excavation or denudation effected on supra-marine land by the erosive force of the pluvial and fluvial waters." "That story," he adds, "is yet to be written."

There are, however, limitations to these changes in the present condition of the earth's surface, some of which are ultimately imposed upon them by their own operation. They were acutely urged by the late Rev. Dr. W. D. Conybeare, a consummate geologist of his time, in his introduction to the 'Outlines of the Geology of England and Wales,' by himself and the late Mr. W. Phillips, and in some papers in the 'Philosophical Magazine' consequent upon the first appearance of Sir C. Lyell's 'Principles of Geology.' From thirty to forty years have elapsed since the publication of his views, which have been almost forgotten, on which account we cite, from the publication first mentioned, some of the most apposite :—"Over a great part of the earth's surface the influence of these wasting causes is absolutely null, the mantle of greensward that invests it being an effectual protection. The burrows of the aboriginal Britons, after a lapse of certainly little less, and in many instances probably more, than two decades of centuries, retain very generally all the pristine sharpness of their outline; nor is the slight fosse that sometimes surrounds them in any degree filled up. Causes, then, which in two thousand years have not affected in any perceptible manner these small tumuli, so often scattered in very exposed situations over the crests of our hills, can have exerted no very great influence on the mass of these hills themselves in any assignable portion of time which even the imagination of a theorist can allow itself to conceive; and where circumstances are favourable to a greater degree of waste, still there is often a tendency to approach a maximum at which farther waste will be checked: the abrupt cliff will at last become a slope, and that slope become defended by its grassy coat of proof. It should appear that even the action of the sea, certainly the most powerful and important of all those we have surveyed, has a similar tendency to impose a limit to its own ravages." Dr. Conybeare also considers, in relation to the permanence of the general surface of the globe, the possible effect on the level of the sea of the quantity of materials carried into it, which he concludes to be absolutely imperceptible—a conclusion amply justified by the recent investigation of Mr. A. Tylor, as noticed in the article SEA, col. 418.

The relation of these and other limitations to the consequences of the modern doctrine referring the mighty operations which have formed and modified our continents to causes now in action, acting also under their present conditions, and with only their present forces, has not been adequately considered by subsequent geologists. Dr. Conybeare's views on this subject, we conceive, in common with those taken by him on other important points in the philosophy of geology, have not received from his successors the consideration they deserve: a circumstance of which the fact of his own withdrawal from the pursuits of science for many of the later years of his life, may afford some explanation.

The subject of the preceding portion of this article is one of physical geography and geology. But we may regard the surface of the globe in a wider philosophical sense, not as confined to that of the land and sea-bed, but as the limit of the extension of the matter constituting our planet; and therefore, also, of a certain class of the actions which maintain it, though not of all the forces to which that matter is subject, some of them extending beyond that limit. In this sense the earth has two surfaces, that of the land and water taken together, and that of the thin spherical shell of air that rests upon and encompasses it. The latter is the termination in space of our planet; the former, the termination of the solid and liquid matter of which the earth, or at least its superficial crust, consists, whatever may be the physical state of the more central interior, of which we know nothing. These surfaces are the final results of the equilibrium which the mutually acting and reacting forces of nature maintain in the globe.

Thus considered, the subject has an interest of its own, independent of the geographical and geological importance of the surface of the land or solid matter. Though the waters form only a residual film, as it were, of certain materials of the crust which are liquid at the mean temperature of the surface, a result of the final equilibrium of the chemical and physical actions taking place below and above, yet their portion of the surface, so much greater than that of the exposed solid matter, or land, has a paramount influence on the constitution of the terminal shell of matter—the atmosphere—with respect to its aqueous constituent. The atmosphere, in like manner, is the resultant residue of the physical and chemical actions taking place upon the terraqueous surface, or below, within reach of the atmosphere, but consisting of materials which are aëriform at the mean temperature of the globe; some, indeed, at all known temperatures; others within a certain range of them.

The definite surface of the terraqueous globe, there is reason to conclude, is repeated in that of the atmosphere, the finite extent of which we conceive to be demonstrated by that of the column of mercury or water, or other gravitating fluid in the barometer. It would appear, on first considering the subject, that the only changes this surface can undergo will be extensive perpetual undulations of the nature of tides, and disturbances occasioned by the entrance and transit, and perhaps by the ignition, of the bodies which become meteors. It may, however, be true, agreeably to the views of Poisson, in particular respects anticipated by Graham and by Luke Howard, and with which also harmonise certain inferences regarding the structure of the higher regions of the atmosphere originally drawn by Mr. Brayley, and virtually adopted by the late Professor Daniell—that the atmosphere has a terminal film of solid matter—frozen air—forming upon a subterminal one of liquid matter—liquefied air—itself passing below into a stratum of air-vapour, and that into a still inferior one of dense air retaining its gaseous condition; the rarest stratum of the air being thus beneath the summit of the atmospheric column, and not constituting the upper surface, as long tacitly assumed, and as indeed would follow from the law of elasticity of the air considered by itself. In this case, in addition to the movements alluded to, the surface of the atmosphere must be in a state of perpetual equilibrated motion and change, the ultimate physical resultant of the continual subversion and restoration of equilibrium, or at least, of the existing tendencies to those conditions, arising from the antagonism of heat and gravitation.

The complex superficial crust of our planet, of which the surfaces of the atmosphere and of the terraqueous globe are the superior limits, is the final result of the action of the sun upon those surfaces, reacted to by the interior forces of the earth, which the sun, as it were, governs, both by its direct action, gravitative, calorific, light-giving, and magnetic; and also indirectly, through that of the waters and the air upon the land, the solid, liquid, and aëriform elements of the crust being thus all subject to its action; while a certain amount of action is also exerted upon them by the radiation of the stars, the suns of other systems. On the surface of the earth, therefore, in its most comprehensive sense, are inscribed the indelible and enduring records of all the activities, terrestrial, solar, and celestial, which have produced, and are perpetually reproducing it; and on that of the terraqueous globe, thus maintained in equilibrium, organic nature and man exist, the well-being of the latter being the end, or final cause, of the whole.

SURFACES OF THE SECOND DEGREE. This name is given to all those surfaces of which the equation is of the second degree, or can be made a case of

$$\begin{gathered} ax^2+by^2+cz^2+2a'yz+2b'zx+2c'xy \\ +2a''x+2b''y+2c''z+f=0, \end{gathered}$$

to which form any equation of the second degree between three variables may be reduced. These surfaces hold the same place among surfaces which is held by curves of the second degree, or conic sections, among curves; and every section made by a plane with any surface of the second degree must be a curve of the second degree. The following article is intended entirely for reference, as the books which treat on the subject hardly ever give the complete tests for the separation of the different cases from each other.

1. The preceding equation may be wholly impossible, or incapable of being satisfied by any values of x, y, and z. This happens when the left-hand side can be resolved into the sum of any number of squares which cannot vanish simultaneously.

2. It may represent only one single point. In this case the left-hand side can be resolved into the sum of three squares, which vanish simultaneously for one set of values of x, y, and z.

3. The equation may belong to a single straight line. In this case the left-hand side can be resolved into the sum of two squares.

4. The two last cases have a particular case which is algebraically very distinguishable from the rest, though it can only be geometrically represented by saying that the point or line is at an infinite distance from the origin.

5. The equation may belong to a single plane. In this case the left-hand side is a perfect square.

6. Or to a pair of planes, either parallel or intersecting. The left-hand side can then be resolved into two different factors of the first degree.

In the preceding cases there is no other surface than can be represented by one or several equations of the first degree. We now come to the cases in which new surfaces, not plane, are generated. But we may first observe that the left-hand side of the equation has a property much resembling a celebrated one of integer numbers. If it be the sum of any number of squares exceeding four, it may be reduced to the sum of four squares at most.

7. The equation may belong to a cone, having for its base any one of the conic sections. But in every case the same cone may be described by a circle only: that is, every cone of the second order is a circular cone, right or oblique. In this case, the first side of the equation takes the form $P^2+Q^2-R^2$, or $P^2-Q^2-R^2$, P, Q, and R being expressions of the first degree, of the form $Ax+By+Cz+E$.

8. The equation may belong to a cylinder having for its base any conic section. But the elliptic, parabolic, and hyperbolic cylinders are perfectly distinct. In this case the first side of the equation can be reduced to the form P^2+mQ^2+nQ, P and Q being expressions of the first degree, and m and n constants.

9. The equation may belong to an *ellipsoid*, a *single hyperboloid*, a *double hyperboloid*, an *elliptic paraboloid*, or an *hyperbolic paraboloid*. These five are the distinct surfaces of the second degree, answering to the three distinct curves of the second degree—namely, the ellipsoid to the ellipse, the two hyperboloids to the hyperbola, and the two paraboloids to the parabola. They will presently be further described; in the mean time the forms to which the left-hand side of the equation may be reduced in these several cases are—

Ellipsoid $P^2+Q^2+R^2-m^2$.
Single Hyperboloid $P^2+Q^2-R^2-m^2$.
Double Hyperboloid $P^2-Q^2-R^2-m^2$.
Elliptic Paraboloid P^2+Q^2+mR.
Hyperbolic Paraboloid P^2-Q^2+mR.

The conditions under which the several cases are produced are exhibited in the following table. Let

$$V_1=a+b+c$$
$$V_2=bc+ca+ab-a'^2-b'^2-c'^2$$
$$V_3=abc+2a'b'c'-aa'^2-bb'^2-cc'^2$$
$$V_4=(bc-a'^2)\,a''^2+(ca-b'^2)\,b''^2+(ab-c'^2)\,c''^2$$
$$+2\,(b'c'-aa')\,b''c''+2\,(c'a'-bb')\,c''a''+2\,(a'b'-cc')\,a''b''$$

$$W=-\frac{V_4}{V_3}+f$$

When $V_3=0$, V_4 is a perfect square: if V_4 also $=0$, the three expressions

$$\frac{ba''^2-2c'a''b''+ab''^2}{ac-c'^2},\ \frac{ac''^2-2b'c''a''+ca''^2}{ca-b'^2},\ \frac{cb''^2-2a'b''c''+bc''^2}{bc-a'^2}$$

are all equal. Let either of them, with its sign changed, and increased by f, be called W'. Again, when any three of the six quantities

$$bc-a'^2,\quad ca-b'^2,\quad ab-c'^2$$
$$b'c'-aa',\quad c'a'-bb',\quad a'b'-cc'$$

vanish, the other three also vanish. Let these vanish, and also let a'', b'', c'' be in the proportion of a, c', b', or of c', b, a', or of b', a', c. When this happens, the three following

$$\frac{a''^2}{a},\quad \frac{b''^2}{b},\quad \frac{c''^2}{c}$$

are equal: let either, with its sign changed, and increased by f, be called W''. The table is then as follows, in which p means either of the signs + or −, and n means the other; and a supposition put in parentheses means that it is a necessary consequence of what precedes or is not independent.

W	V_3	W'	V_2	W''	V_1	Surface.
p	p		+		p	Impossible.
p	n		+		n	Ellipsoid.
p	p		+		n	Single Hyperboloid.
p	p		−			do. do.
p	n		+		p	Double Hyperboloid.
p	n		−			do. do.
∞	(0)		+			Elliptic Paraboloid.
∞	(0)		−			Hyperbolic Paraboloid.
0	p		+		p	Point.
0	p		+		n	Cone.
0	p		−			do.
$\frac{0}{0}$	(0)	p	+		p	Impossible.
		p	+		n	Elliptic Cylinder.
			−			Hyperbolic Cylinder.
		∞	(0)			Parabolic Cylinder.
		0	+			Straight Lines.
		0	−			Intersecting Planes.
		$\frac{0}{0}$	(0)	p	p	Impossible.
				p	n	Parallel Planes.
				0		Single Plane.
				∞		

For example, it is the condition of an ellipsoid that W and V_3 should be finite with different signs, that V_2 should be positive, and V_1 of the same sign as V_3: it is the condition of intersecting planes that W should have the form $0\div 0$, or that V_4 and V_3 should both vanish: that W' should also vanish; and that V_2 should be negative. It is the condition of a single hyperboloid, if V_2 be positive, that W and V_3 should both differ in sign from V_1; but if V_2 be negative, it is enough that W and V_3 should have the same sign. All that precedes is equally true whether the co-ordinates be oblique or rectangular; but the following is only true for rectangular co-ordinates: if the surface be a surface of revolution, it is necessary that

$$\frac{b'c'-aa'}{a'}=\frac{c'a'-bb'}{b'}=\frac{a'b'-cc'}{c'}.$$

The forms of the ellipsoid and of the two hyperboloids may best be conceived by means of the particular cases in which they are surfaces of revolution. Let an ellipse revolve about one of its axes, and let all the circular sections be flattened into ellipses: the result will be an ellipsoid, derived from its particular case, the spheroid. Let an hyperbola revolve about its minor axis; the two branches will generate only one branch of a surface: let the circular sections be flattened into ellipses, and the result is the single hyperboloid. Let the hyperbola revolve about its major axis: the two branches will generate two branches of a surface; and if the circular sections be flattened into ellipses, the result is the double hyperboloid. For the elliptic paraboloid, let a parabola revolve about its principal axis, and let the circular sections become ellipses. The hyperbolic paraboloid has no surface of revolution among its cases, but its form may be conceived as follows:—Let two parabolas have a common vertex, and let their planes be at right angles to one another, being turned contrary ways. Let the one parabola then move over the other, always continuing parallel to its first position, and having its vertex constantly on the other: its arc will then trace out an hyperbolic paraboloid.

The ellipsoid and the two hyperboloids have centres, but neither of the paraboloids has one. The surfaces which have centres possess an infinite number of triple systems of diameters having properties corresponding to those of the conjugate diameters of an ellipse and hyperbola. These we shall not describe, but shall proceed to point out how to determine the position of the centre and principal diameters or axes (that is, the system of conjugate diameters, each of which is at right angles to the other two) in either of the surfaces having a centre. Resuming the original equation, and the co-ordinates being supposed rectangular, the co-ordinates of the centre, X, Y, and Z, are thus determined. They are fractions whose denominator is $-V_3$, and whose numerators are

$$(bc-a'^2)a''+(a'b'-cc')b''+(c'a'-bb')c''$$
$$(ca-b'^2)b''+(b'c'-aa')c''+(a'b'+cc')a''$$
$$(ab-c'^2)c''+(c'a'-bb')a''+(b'c'-bb')b''\,;$$

and if the origin be removed to the centre, the axes retaining their original directions, the equation of the surface becomes

$$ax^2+by^2+cz^2+2a'yz+2b'zx+2c'xy+W=0,$$

where W is the expression already signified by that letter, and will be found to be also $Xa''+Yb''+Zc''+f$.

Let the three principal axes now make angles with the axes of x, y, and z, as follows:—The first, angles whose cosines are α, β, γ; the second, angles whose cosines are α', β', γ'; the third, angles whose cosines are α'', β'', γ''. The equation

$$r^3 - \mathrm{V}_1 r^2 + \mathrm{V}_2 r - \mathrm{V}_3 = 0$$

has always three real roots; let them be A, A', A''. Then the directions of the principal axes are to be determined from

$$\alpha^2 = \frac{bc - a'^2 - (b+c)\mathrm{A} + \mathrm{A}^2}{(\mathrm{A}-\mathrm{A}')\,(\mathrm{A}-\mathrm{A}'')}$$

$$\beta^2 = \frac{ca - b'^2 - (c+a)\mathrm{A} + \mathrm{A}^2}{(\mathrm{A}-\mathrm{A}')\,(\mathrm{A}-\mathrm{A}'')}$$

$$\gamma^2 = \frac{ab - c'^2 - (a+b)\mathrm{A} + \mathrm{A}^2}{(\mathrm{A}-\mathrm{A}')\,(\mathrm{A}-\mathrm{A}'')}.$$

To find α'^2, &c., interchange A and A' in the above; and to find α''^2, &c., interchange A and A''. The principal axes being thus determined, the equation to the surface, referred to the principal axes, is

$$\mathrm{A}x^2 + \mathrm{A}'y^2 + \mathrm{A}''z^2 + \mathrm{W} = 0,$$

a form which is fully considered in all elementary works on the subject, and from which the principal properties are derived. ('Algebraic Geometry,' in the Library of Useful Knowledge.)

For the proofs of the preceding assertions, and their extension to oblique co-ordinates, see a paper 'On the General Equation of Surfaces of the Second Degree,' in the 'Cambridge Philosophical Transactions,' vol. v., part 1. Under the form of considering the surface of the second degree, we have in fact been treating the general properties of the equation of the second degree, with three variables, and have solved various other problems of geometry and mechanics. The principles applied in this solution have been generalised in a paper on 'Linear Transformations,' by Mr. Boole. ('Cambr. Math. Journ.,' vol. iii., p. 1.)

SURGEONS, COLLEGE OF. The present College of Surgeons of England had its origin in the Company of Barber-Surgeons, which was incorporated by royal charter in the first year of Edward IV. By this charter of 1 Edward IV., the barbers practising surgery in London, who had before associated themselves in a company, were legally incorporated as the Company of the Barbers in London. Their authority extended to the right of examining all instruments and remedies employed, and of bringing actions against whoever practised illegally and ignorantly; and none were allowed to practise who had not been previously admitted and judged competent by the masters of the company.

This charter was several times confirmed by succeeding kings, but in spite of it many persons practised surgery independently of the company, and at length associated themselves as members of a separate body, and called themselves the surgeons of London. In the 3rd year of Henry VIII. it was enacted "that no person within the city of London, or within seven miles of the same, should take upon him to exercise or occupy as a physician or surgeon, except he be first examined, approved, and admitted by the bishop of London or by the dean of St. Paul's for the time being, calling to him four doctors of physic, and for surgery other expert persons in that faculty." All who under this act obtained licence to practise were of course equally qualified, whether members of the company of barbers or not; and in the 32nd year of Henry VIII. the members of the latter company, and those who had incorporated themselves as the company of surgeons, were united in one company, "by the name of masters or governors of the mystery and commonalty of barbers and surgeons of London."

In the 18th year of George II. an act was passed by which the union of the barbers and surgeons was dissolved, and the surgeons were constituted a separate company; and in the 40th year of George III. a charter was granted by which it was confirmed in all the privileges which had been conferred upon it by the act of George II. By this charter the title of the company was altered from that of the masters, governors, and commonalty of the Art and Science of Surgeons to that of the Royal College of Surgeons in London. Under this charter it was governed by a council or court of assistants, consisting of twenty-one members, of whom ten composed the court of examiners. Of these ten one was annually elected president, or principal master, and two were annually chosen vice-presidents or governors. By the bye-laws which the council were empowered by the charter to make, the members of the council were to be chosen for life from those members of the College whose practice was confined to surgery, and were to be elected by ballot at a meeting of the council. The examiners were generally chosen in order of seniority from the members of the council: the presidents and vice-presidents were chosen in rotation from the court of examiners, the president for the current year having been the senior vice-president during the past year.

A new charter was granted to the College of Surgeons in the 7th year of Victoria, by which it is declared, that the name of the college shall henceforth be The Royal College of Surgeons of England; and that a portion of the members of the said college shall be fellows thereof, by the name of The Fellows of the Royal College of Surgeons of England. The charter declares that the present president and two vice-presidents and all other the present members of the council of the said college, and also such other persons, not being less than 250 nor more than 300, and being members of the said college, as the council of the college, at any time before the expiration of three calendar months from the date of the charter, shall elect and declare to be fellows in manner by the charter directed; together with any such other persons as the council of the said college, after the expiration of the said three calendar months and within one year from the date of the charter, shall appoint in manner by the charter authorised, shall be fellows of the said college. But no person, except as hereinbefore named, is to become a fellow, unless he shall have attained the age of twenty-five years, and complied with such rules as the council of the college shall think fit, and by a bye-law or bye-laws direct; nor unless he shall have passed a special examination by the examiners of the said college. Every person admitted as a fellow, as last mentioned, is to become a member of the College by such admission, if he is not already a member. Henceforth, no member of the College, who is not a fellow, is to be eligible as a member of the council. There are also (10) some other restrictions as to eligibility. The present members of the council are to continue life members as heretofore; and the number of members of council is to be increased from twenty-one to twenty-four, and all future members are to be elective, and to be elected periodically, in the manner prescribed by the charter (12) when the number of elective members of the council shall be completed and made up to twenty-four. Three members shall go out annually, but they may be re-elected immediately. The members of council are to be elected by the fellows, including the members of the council as such, in the manner prescribed by the charter (15); and the election is to be by ballot (17). There are various special provisions as to the eligibility of fellows, for which we refer to the charter. There are to be ten examiners of surgeons for the college, and the present examiners are to continue for life; and all future examiners are to be elected by the council, either from the members of the council, or from the other fellows of the college, or from both of them; and all future examiners of the college shall hold their office during the pleasure of the council. The charter contains other regulations, and confirms the powers of the college and the council, except so far as they are altered by the charter; and it declares that no bye-law or ordinance hereafter to be made by the council shall be of any force until the crown shall have signified its approval thereof to the college under the hand of one of the principal secretaries of state, or otherwise as in the charter stated (22). "The Bye-Laws and Ordinances of the Royal College of Surgeons of England" contain the regulations as to the candidates for the fellowship (sect. 1), for the examination of candidates for the fellowship (2), admission of fellows (3), election of members of council (5). By section 1, it is required that every candidate for the fellowship, among other certificates, shall produce a certificate, satisfactory to the court of examiners, that he has attained a competent knowledge of the Greek, Latin, and French languages, and of the elements of mathematics. The subjects of examination for the fellowship are Anatomy and Physiology on the first day, and Pathology and Therapeutics and Surgery on the second day. The examination is to be by written answers to written or printed questions; but any candidate may be interrogated by the examiners, on any matter connected with the questions or answers. In the anatomical examination the candidate must also perform dissections and operations on the dead body in the presence of the examiners.

By a recent bye-law members are eligible to the fellowship by election. Any member of the College, of fifteen years' standing, who was a member on the 14th of September, 1843, desirous of admission to the fellowship otherwise than by examination, must sign a declaration of not selling or supplying drugs or medicines, which must be accompanied by a certificate recommending him to the fellowship, signed by six fellows of the college. The signing of the certificate is subject to some alterations for surgeons in the army and navy, and in the British colonies.

Persons are admitted to examination for the membership of the College on producing certificates of being twenty-one years of age; of having been engaged four years in the acquirement of professional knowledge, and of having attended lectures on anatomy, surgery, and other branches of professional knowledge for four years; of having dissected and attended hospital practice during three winter and two summer sessions.

The examination for the diploma of member is divided into two parts, the first relating to anatomy and physiology, the second relating to pathology, surgery, and surgical anatomy. The latter examination is partly written and partly oral. The examination on anatomy is on the recently dissected subject. Students who have completed their second session of anatomical studies are eligible for undergoing the first part of this examination.

The College also gives an especial certificate of qualification for the practice of midwifery. Members or fellows of the College previous to the 1st of January 1853, are eligible to this examination at once. Members or fellows admitted since 1853 have to produce a certificate of having attended at least twenty labours. Members of other Colleges of Surgeons, or graduates of universities, are also admitted to examination for this certificate. Persons not having any diploma, but producing evidence of having completed their professional education, and of having attended one course of lectures on midwifery, and of having personally attended thirty labours, are also admitted to examination for this certificate.

By the new medical act (21 & 22 Vict. c. 90, s. 48), it was enacted that it shall be lawful for her Majesty to grant to the Royal College of Surgeons power to institute and hold examinations for the purpose of testing the fitness of persons to practise as dentists, who may be desirous of being so examined, and to grant certificates of such fitness. The college has since granted a large number of certificates to persons practising as dentists alone.

The Licentiates of the Royal College of Surgeons in Ireland, of the Royal College of Surgeons of Edinburgh, and of the Faculty of Physicians and Surgeons of Glasgow are admissible to the membership of the College under the bye-laws relating to *ad eundem* admissions.

The museum of the College consists of the collection made by John Hunter, which was given in trust by government, who purchased it for 15,000*l.*, and of numerous additions made to it by donations of members and others, and by purchase. The parts of it which illustrate physiology, palæontology, and morbid anatomy are probably the most valuable collections of the kind in Europe. [HUNTER, JOHN, in BIOG. DIV.]

Lectures on anatomy, for which 510*l.* were left to the company of barber surgeons by Edward Arris, and 16*l.* per annum by John Gale, are delivered annually by one of the members of the council or some other member selected by them. Twenty-four museum lectures are also, in compliance with the deed of trust, annually delivered by the Hunterian professor, the subjects of which must be illustrated by preparations from the Hunterian collection, and from the other contents of the museum. An oration in commemoration of John Hunter, or of others who have been distinguished in medical science, is delivered annually on the 14th of February, the anniversary of Hunter's birth.

The College gives also three prizes for the best essays on anatomical and surgical subjects; one, "the Collegiate Triennial Anatomical Prize of fifty guineas;" the other two, "Jacksonian Prizes" of twenty guineas each, are given every year.

The library is very extensive, and is open to all students, members and fellows, from 10 till 4 o'clock.

Abstracts of the several acts and charters relating to the College of Surgeons may be found in Willcock, 'On the Laws relating to the Medical Profession,' London, 1830, 8vo, and in Paris and Fonblanque's 'Medical Jurisprudence,' vol. iii. The bye-laws, the list of members, the catalogues of the museum and library, &c., are published by the College.

SURINAMINE. An alkaloid of unknown composition found in the bark of a plant of the genus *Geoffræa* growing in Surinam and Jamaica.

SURNAME. [NAME.]

SURPLICE, the white dress worn by the clergy in their acts of ministration, from the Latin *superpelliceum*. It differs from the *albe* in having wider sleeves. It appears to have been introduced in order to make a distinction between the dresses which the superior and the inferior orders of the clergy wore at the Liturgy; and from about the 12th century the name of surplice was introduced. During the middle ages, bishops very frequently wore the surplice with a cope, and above the rochette. (Bona, *Rerum Litury.*, lib. i., cap. 24, s. 20; Palmer's *Orig. Liturgicæ*, vol. ii.)

SURRENDER. "*Sursum redditio* properly is a yielding up of an estate for life or years to him that hath an immediate estate in reversion or remainder, wherein the estate for life or years may drown by mutual agreement between them." A surrender and a release both have the effect of uniting the particular estate with that in reversion or remainder; but they differ in this, that whereas a release generally operates by the greater estate descending on the less, a surrender is the falling of the less estate into the greater.

Coke mentions three kinds of surrenders: 1. A surrender at common law, which is the surrender properly so called; 2. A surrender by custom of copyhold lands or customary estates; and, 3. A surrender improperly taken, as of a deed, a patent, of a rent newly created and of a fee-simple to the king.

1. The surrender at common law is of two sorts: 1. A surrender in deed or by words in writing, expressing the intention of the owner of the particular estate to yield it up to him in reversion or remainder; and, 2. A surrender in law, which is wrought by operation of law, and not actual; as if a lessee for life or years takes a new lease of the same land during the continuance of his term, this will be a surrender in law of the prior lease.

The surrender of terms of years will sometimes be presumed from length of time alone; and many cases have arisen upon the question, after what periods mortgage terms have been satisfied, and terms which have been assigned to trustees to attend the inheritance and have not been subsequently dealt with, will be presumed to have been surrendered.

2. As to surrender of copyholds, see COPYHOLD.

3. A surrender may be made of letters-patent and offices to the crown, to the intent that a fresh grant be may made of the same right; and a grant of the second patent for years to the same person, for the same thing, causes a surrender in law of the first.

SURROGATE, is, according to Cowell's 'Interpreter,' "one that is substituted or appointed in the room of another, most commonly of a bishop or a bishop's chancellor."

The qualifications required in a person appointed as surrogates are defined and enforced by the canons of 1603. He must be a grave minister and a graduate or a licensed preacher and beneficed, or a bachelor of law or a master of arts, well qualified from his religion and learning.

Surrogates being delegated officers, their jurisdiction of course depends upon that of the person for whom they act. The principal duty however of ecclesiastical surrogates may be stated to consist of taking affidavits in the ecclesiastical courts and granting marriage licences. The proper performance of these duties is guarded by particular enactments. By the 26 Geo. II. c. 33, § 7, every surrogate deputed by any ecclesiastical judge who has power to grant licences of marriage is required, before granting any such licence, to take an oath before such judge and to give a bond of 100*l.* to the bishop of the diocese for the faithful execution of his office.

Surrogates are also persons appointed to execute the offices of judges in the courts of Vice-Admiralty in the colonies, in the place of the regular judges of those courts. The acts of such surrogates have, by the 56 Geo. III., c. 82, the same effect and character as the acts of the regular judges.

SURVEYING is the art of determining the form and dimensions of tracts of ground, the plans of towns and single houses, the courses of roads and rivers, with the boundaries of estates, fields, &c. A survey is accompanied by a representation on paper of all the above-mentioned objects, and frequently by a delineation of the slopes of the hills, as the whole would appear if projected on a horizontal plane. When canals or railways are to be executed, a survey of the ground is combined with the operations of levelling, in order to obtain, besides a horizontal plan, the forms of vertical sections of the ground along the proposed lines, and thus to ascertain the quantities of earth to be removed.

In maritime surveying, the forms of coasts and harbours, the entrances of rivers, with the positions of islands, rocks, and shoals, are to be determined; also the soundings or depths of water in as many different places as possible.

Military surveying consists chiefly in representing on paper the features of a country, such as the roads, rivers, hills, and marshes, in order to ascertain the positions which may be occupied as fields of battle or as quarters; and the facilities which the country may afford for the march of troops or the passage of artillery stores.

For trigonometrical surveying, see TRIGONOMETRY.

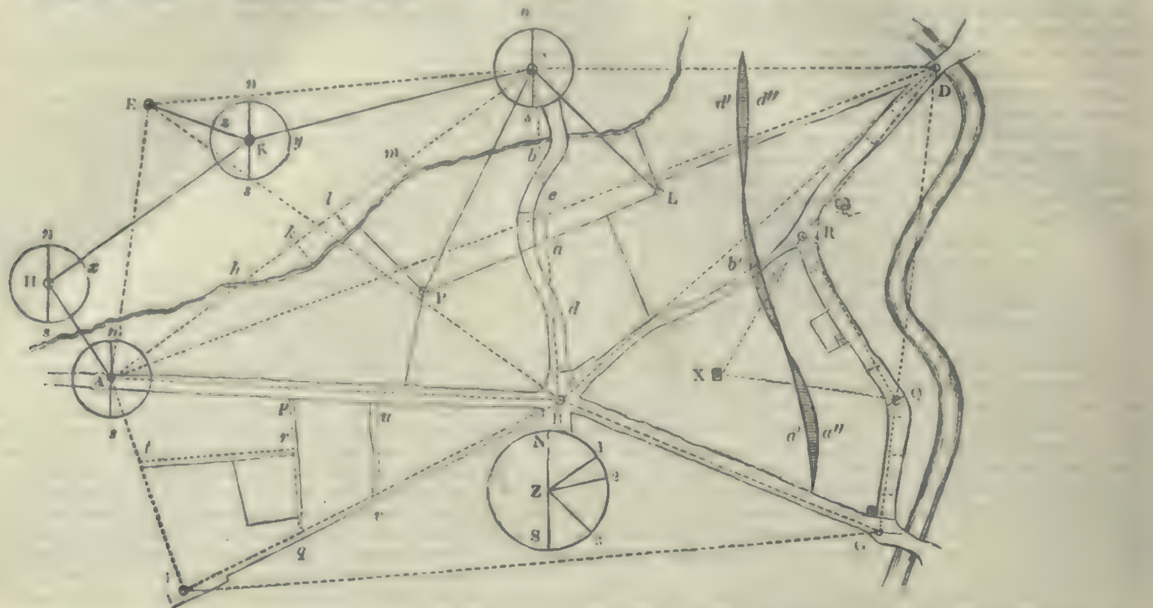
Since the measurement of the distance between two objects by means of a rod or chain is very laborious and inaccurate when that distance is considerable, particularly if the ground should have many inequalities of level, and be much intersected by walls, hedges, and streams of water, it will seldom be possible to execute even an ordinary survey by such means alone, and instruments for taking angles must be employed, together with the chain, in every operation of importance.

If within the tract to be surveyed there should be a road about half a mile in extent, and nearly straight and level, so that a line may be accurately measured upon it by the chain, and that from its extremities several remarkable objects, as churches or mills, may be seen, it will be convenient to use such measured line as a base, and with a theodolite to observe the angles contained between the base and the lines joining the extremities to the different objects. The three angles of each triangle formed by such lines should if possible be observed, in order that by the agreement of their sum with 180° the accuracy of the angular measurements may be tested; and then the lengths of the sides of the triangles may be determined by the rules of plane trigonometry.

Let A B represent a base so measured in a road; and let C, D, E, F be four remarkable objects within or near the boundaries of the tract to be surveyed; the distances A C, A D, &c., B D, B C, &c., will be those which should be determined by computation. These lines may then serve as bases, and if from their extremities be taken the angles contained between them and lines supposed to connect them with any other objects, as houses or remarkable trees, the positions and distances of these objects may be determined by computation as before. Thus B C or B D will serve as a base by which the position of G may be computed.

It will obviously be advantageous if the lines supposed to connect the objects lie nearly parallel to the directions of roads, lanes, streams, or hedges, on account of the facility which will thereby be afforded for laying down such roads, &c., on the plan. In order that it may be possible to place the theodolite at the angular points of the triangles, those points should not be precisely in the churches, mills, or other objects whose positions are to be determined, but should be indicated by poles set up near those objects, on spots of ground in such situations that each may be visible from the two others which with it constitute the intended triangle. The place of the building may be ascertained by its bearing and distance from the pole in its vicinity. After as many stations as may be thought fit have been determined in the manner just described, and the lengths of the lines (that is, the sides of the triangles) connecting them have been computed, the survey may be completed by actual admeasurements with the chain, in each triangle separately.

Poles having been set up at the angular points of every triangle, the surveyor and his assistant set out from any one of these points, as B, and proceeding across the ground, measure the whole length of any one line, as B C, leaving pickets in the ground in the direction of the line at or near every place where it crosses a hedge, as at *a*, a stream, as at *b*, a road, or any other object which is to be introduced in the plan. Should it happen that the line B C, or any part of it, coincide with the direction of a road, offsets, as they are called, are measured perpendicularly to the line, on one or both sides of it, in order to express the distance from the line to the sides of the road, or to the hedges or walls along those sides; these offsets (which are shown at *c*, *d*, and *e*) should be measured at the end of every chain's length, and particularly at every point in the station line opposite to which there is a remarkable object, as a house, a gate, or merely a bend in the direction of the road. Thus, when the work is laid down on paper, the precise form and breadth of the road will be expressed.



In like manner the other side, A C, of the triangle, is to be measured with the chain; pickets are to be left in the ground at or near every place where a stream, as at *h*, a road, or a hedge crosses the side of the triangle; and offsets, as at *k*, *l*, *m*, are to be measured from the station line to and across such boundaries as may be nearly parallel to any part of its direction. The like process is to be followed on each side of every triangle; the measured lengths of the sides of each triangle should then be compared with the computed lengths; and if the difference be not considerable, the work may be considered as having been performed with sufficient accuracy; otherwise the operations must be repeated, in order that the source of the error may be detected.

To carry on the work in the interior of any angle, as A B F, the surveyor, where it is possible, measures with the chain the direct distance from the pickets in one side of the triangle to the pickets in another side, as *nv*, *pq*; and since these pickets are supposed to have been placed near the intersections of boundary-lines (roads, streams, or hedges) with the sides of the triangle, the lines last measured will, at least in part of their length, coincide with or be parallel to some of the boundaries in the interior of the triangle; and the precise figures of such boundaries will be determined as before by offsets from the measured line to all the principal bends. The length of each of these secondary station lines may be obtained by trigonometry, since the line is the base of a secondary triangle of which the two sides are known, being measured parts of two sides of the principal triangle, and the angle included between those sides has been found by the theodolite; therefore the measured length of this line, on being compared with the computed length, will afford an additional test of the accuracy of the work.

In measuring these secondary lines within each principal triangle, pickets must, as before, be left in the ground in the direction of the line, at or near places, as at *r*, where hedges, walls, &c., cross the line; and from one of these pickets, *r*, to another, as *t*, lines are afterwards to be measured (these being as much as possible in or near the direction of other boundaries), till at length the whole interior of each principal triangle will have been divided into several secondary triangles, all the sides of which have been measured. These sides, by means of the offsets which have been measured from them, determine the figures of all the natural and artificial boundaries within the tract of ground.

The situations of the buildings are also determined by offsets from the station lines nearest to them: the ground plans of the more considerable edifices, as churches and mansions, are measured, and the directions of their fronts with respect to the meridian are ascertained by a compass or otherwise.

When rivers or roads have many abrupt and deep bends, the determination of their forms by means of offsets from the station-lines may become impracticable; and then a separate survey of such details must be made by means of the compass, the circumferentor, or the theodolite. [THEODOLITE.] The same means must be employed for the survey of a sea-coast, when the operation is to be performed on land; and it may often be advantageous to determine in like manner the forms of the hedges, walls, &c., in the interior of the tract which is to be surveyed. Ground covered with wood must be surveyed by going quite round it; poles being set up at remarkable bends on the contour, the distances between them are measured with the chain, and the bearings of the several lines from the meridian are observed with the theodolite.

In order to explain the process of surveying with the theodolite by the method which is commonly called that of the "back-angle," and which is now almost constantly adopted, let it be required to determine the outline H K C L B A, which may represent the contour of a wood, or of which part may coincide with the course of a road or river. The instrument may be set up at H, which may be supposed to be the first station; and let the line *n s* at each of the stations H, K, C, &c., represent the position of the needle or of the magnetic meridian at the station: also let the instrument be adjusted so that the zero point of the horizontal limb may be under the point *n* (the north point of the needle), or the zero of the degrees in the compass-box may be in coincidence with *n*; and let K be the second station. Turn the upper horizontal plate with the telescope till the object-glass of the latter is directed to K, and make the intersection of the wires appear to coincide with the object at that station; then the index of the vernier will be at some graduation on the lower horizontal plate, as at *x*, and the angle *n* H K is that which is observed; suppose it to be 54°, reckoning from the north towards the east, which angle is usually represented by N. 54° E. [N.B. Previously to directing the object-glass to K, it might have been directed to any other visible objects, as F or D, whose positions it might be required to determine by means of their bearings from the meridian line.]

Let the theodolite be now removed to K, a staff being planted in the ground at H: turn the whole instrument round on its vertical axis (the index of the vernier remaining at the graduation N. 54° E.) till the object-glass of the telescope is directed to H, and the intersection of the wires appears to coincide with the staff there. Then, if the former angle were correctly taken, and no movement of the horizontal plates on one another have taken place, the south point *s* of the needle will lie over the zero of the graduations on the lower plate, or will coincide with the zero of the degrees in the compass-box; and this circumstance will be a proof of the accuracy of the work, all the meridian lines *n s*, *n s*, being supposed to be parallel to one another.

Now turn the upper horizontal plate with the telescope, till the object-glass of the latter is directed to C, and the intersection of the wires appears to coincide with the object there: the telescope in moving from the position K H to the position K C having passed over and beyond *s*; and the index of the vernier being supposed to be at *y*, the number of the graduation, these being read from *s* in the direction *sny*, will be greater than 180: let it be 256 (or 180° + 76°): in that case the observed angle is N. 76° E., and it expresses the bearing of the line K C from the meridian *n* K *s*, or from the meridian *n* H *s*. If the telescope in moving from K H should be directed to an object at E, then, the index of the vernier being supposed to be at *z*, the number of the graduation will be less than 180°: let it be 110 (or 180°—70°); in that case the observed angle is N. 70° W., and it expresses the bearing of the line K E from the meridian *n* K *s* or *n* H *s*.

Let the theodolite be removed to C, a staff being left at K, and turn the whole instrument, the index of the vernier remaining at N. 76° E., till the object-glass of the telescope is directed to K, and the intersection of the wires appears to coincide with the staff there; then the point *n* of the needle should lie over the zero of the graduations. Now turn the upper horizontal plate till the object-glass of the telescope is directed to L, and the intersection of the wires appears to coincide with the object there; then the telescope, in turning from the position C K to C L, passing over and beyond *s*, the number of the graduation coincident with the index of the vernier will (reckoning from zero at *n*) be less than 180; let it be 133°: in that case the observed angle is N. 133° E., or S. 47° E., and it expresses the bearing of the line C L from the meridian *n* C *s* or *n* H *s*. If the telescope should not pass beyond *s*, and should be in the position C P, for example, the number of the graduation, reckoned from *n*, will be greater than 180; let it be 206, or 180° + 26°: in that case the observed angle is S. 26° W., or N. 206° E., or N. 154° W., and it expresses the bearing of the line C P from *n* C *s* or *n* H *s*. In this manner the process of the survey is continued to the end of the road, or till, having passed completely round the wood, the instrument returns to H, from whence it set out.

As, from local attractions or other causes, the polarity of the needle may not be constant, it is scarcely to be expected that the needle should, when the telescope is directed back to a preceding station, be exactly coincident with the north and south line in the compass-box: yet a near approach to such coincidence will serve to detect the existence of considerable errors in the observed angles; and a complete verification of the whole series of operations will be obtained, should the observed bearing of H from the meridian line *n* A *s* at the last station A, that is, the angle *n* A H, be found to agree with the observed bearing of A from the meridian line *n* H *s* at the first station H. When this agreement takes place the work is said to close accurately.

The survey of a road or an enclosure, by following the course of the former, or the contour of the latter, may be performed by simply observing with a surveying-compass or a circumferentor the bearings of the several station-lines from the magnetic meridian, and measuring their lengths; and one of these instruments is generally employed when great accuracy is not required.

The plane table, which is also occasionally employed for surveying ground, is a square board fitted upon a tripod-stand and furnished with compass, and with an *alidade*, or ruler carrying "sights" at the extremities. Drawing-paper is made fast to the board or table, and the instrument being set up at any part of the ground which may be thought convenient, a point is marked on the paper to represent the place. The alidade is next turned about that point, so that the line of the sights may be directed to any remarkable objects whose situations are to be determined, and lines are drawn by the edge of the ruler in its several positions: then the distance from the instrument to some one of those objects being measured, and laid down on its line of direction by a convenient scale, the place of that object on the paper is obtained. The table is then removed to that object, and fixed by the needle in the compass-box, so that its edges may be parallel to their former positions; that is, till the alidade placed on the line joining the places of the two objects of the paper is in a direction tending to the former place of the instrument. In this position, the alidade being turned about the point which represents the actual place of the instrument on the ground, lines are drawn as before along the edge of the ruler, towards the several objects which had been observed at the preceding station; the intersections of these lines with the others will determine the places of the objects on the paper.

The length of every line which is to be measured must be obtained in a direction parallel to the horizon between its extremities; and the determination of this length is generally a work of considerable difficulty on account of the inequalities of the ground.

Where great precision is required, it would be proper that the direction of the line to be measured should be indicated by pickets previously planted at intervals along it; a cord may be stretched tight between the two first pickets, and the measurement may be performed by means of a graduated deal-rod 15 or 20 feet in length, which should be applied successively to the cord, the place of each extremity of the rod being marked by a pin pressed into the cord. But when the ground is nearly level, a measuring-chain is laid upon the ground itself in the direction of the line to be measured, the leading man pressing into the ground, at the end of each chain's length, an iron pin, which being taken up by the person who follows, the number of pins so taken up serves to show the number of chains in the length of the line measured. In ascending or descending any gentle elevation of the ground, the chain should be held up at the lower end till it is in a horizontal position, as nearly as the chain-holder can estimate it; and a plummet being suspended from that extremity, so as to touch the ground vertically under it, the measurement thus obtained is in general sufficiently near the required horizontal length of the line. When the slope of the ground is too great to admit of this simple method being put in practice, the chain must be stretched on the ground, and then the angle at which it is inclined to the horizon being found by some instrument (a small spirit-level furnished with a graduated arc), the horizontal value of the chain's length must be computed. And if, at the same time, the vertical height of one end of the chain above the other be also computed, there will be afforded sufficient data for determining on paper the form of a vertical section of the ground in the direction of the measured line.

Where the rise or fall of the ground is considerable, the operation will be most conveniently and accurately performed by the use of a theodolite; for this purpose pickets should be set up in the ground, in the direction of the line to be measured, at every place where a change occurs in the inclination of the ground to the horizon, and marks made on them at heights above the ground equal to that of the telescope belonging to the theodolite; then, while the chainmen are employed in measuring the length of the line on the ground, the surveyor takes the angular elevations or depressions of the marks on the pickets, with respect to the horizon. From the data thus obtained the horizontal distances between points of ground, and the positions of the points above or below any assumed horizontal plane, can be computed. In order to save the trouble of making trigonometrical computations, the vertical arch of the theodolite usually carries two series of graduations, from which, by inspection, when the telescope is directed to an object, the portion of the measured line which should be subtracted from it in order to reduce it to the corresponding horizontal length may be found; and also the portion of that horizontal length to which the vertical height or depression is equal.

This method may be conveniently put in practice when it is required to exhibit sections of the ground, for the purpose of guiding the civil engineer in the choice of a line for a road or canal; the great accuracy with which the section might be determined by a spirit-level not being requisite. It is now the practice to represent on a plan of the ground a vertical section in the direction of a proposed line of road, for the purpose of showing the depths to which the excavations are to be carried, and the heights to which the embankments are to be raised; a strong line, as a', b', d', representing the surface of the proposed road: on one side of this line, as at a'', d'', are shown the profiles of the requisite excavation; and on the other side, as at b'', are shown the profiles of the embankments: both the heights and depths being determined with relation to the surface of the road. This method was first proposed by Mr. Macneil.

The principal and secondary station-lines constitute a triangulation on the plan of the ground; and when the lengths of these lines have been ascertained by admeasurement, the superficies of the whole track may be found by the rules of mensuration. The area of each triangle should be calculated separately from the measured lengths of the lines, and the several results added together, if all the triangles lie within the given boundaries of the tract; should any of them lie on the exterior of the boundary, the areas must of course be subtracted. But as the boundaries of the several fields, &c., seldom coincide exactly with the station-lines, offsets must have been measured from every such line to each remarkable bend in the nearest boundary; and between the station-line, the boundary, and every two offsets from the former, there exists a small trapezoid, whose area must be computed separately, and either subtracted from or added to the areas of the triangles formed by the measured station-lines, according as it lies within or on the exterior of these triangles.

The accurate method just described is not always put in practice by surveyors. When the boundaries of a field or tract of ground have numerous small bends, a straight line is sometimes drawn through portions of the boundary in such a manner that the small areas on the exterior of the line shall be equal to those which fall in the interior, this equality being estimated by the eye: the complex figure of the contour line is thus reduced to one more simple; and the area of the field or tract is then computed. For this purpose either the plan is divided into two or more triangles, or by a geometrical construction the whole irregular figure is reduced to one triangle of equal magnitude, and in either case the lengths of the sides are measured by the scale of the plan.

When a road, river, or any boundary-line is surveyed with the theodolite and chain, the successive operations are registered in a book according to a particular form, by which a person without any knowledge of the ground may be enabled with facility to lay the work down on paper. This is called the 'Field-Book,' and the manner of entering in it the series of operations will be best explained by means of an example. Let G, Q, R, D, be the principal bends in the direction of a road, and the stations at which, in succession, the theodolite is placed for the purpose of observing the bearings of the several lines G Q, Q R, and R D, from the magnetic meridian passing through the first station G.

At G let the bearing of the object, or mark set up at Q, be observed; let the line G Q be measured with the chain, and let offsets be measured perpendicularly to that line up to any remarkable points near it. At Q let the bearing of a staff at R be observed; also let the length of

Q R, and of several offsets from it at remarkable points towards the right and left hand along that part of the road, be measured. Again at R let the bearing of the staff at D be observed; let also the length of R D, and of various offsets along that line, be measured; and let it be supposed that the like process is continued as far as may be required.

Each page of the field-book is then divided, as below, into three columns by two parallel lines drawn down the page: and beginning at the bottom of the column, the several bearings of objects, the lengths of the station-lines, and the several offsets from those lines are inserted, in order, ascending towards the top of the page, the offsets being placed on the right or left hand of the middle column, conformably to their positions with respect to the station-line to which they belong. And it is on this account that the several entries are made in succession from the bottom upwards. The distances in the middle column between the stations G and Q are reckoned from G; those between Q and R are reckoned from Q, and so on, each number in that column expressing the distance up to the place in the station-line where the offset whose length is given immediately on the right or left hand of the number was taken. When it is required to determine by observed bearings the position of any object, as X, at a distance from the road, those bearings are also inserted in the field-book at the stations, as Q and R, where they were observed, and immediately under the bearing of the next forward station. The mark ⊙ is usually put to signify the word "station."

FORM OF THE FIELD-BOOK.

	⊙	4,	600	at D, near the bridge.
	30		500	10
45	0		300	
40	10		200	
45	5		100	40 to a tree.
40			0	45 to a gate.
			N. 40° E.	⊙ 4 (D)
House X.			S. 31° W.	
			at ⊙ 3 (R)	
	⊙	3,	500	two roads unite.
	35		400	15
	42		300	10
To a house	30		200	15
	25		100	15
	30		0	25
			N. 30° 20′ W.	⊙ 3 (R)
House X.			N. 82° W.	
			at ⊙ 2 (Q)	
	⊙	2,	350	
	12		300	40
	20		200	32
To hedge by roadside	15		100	30
To a cottage	10		20	50 to side of road.
			0	60 to the river.
			N. 7° E.	
			at ⊙ 1 (G)	near the bridge.

The term "plotting" is applied to the process of laying down on paper the plan of the ground which has been surveyed. If the survey has been performed by the chain only, the several station-lines constitute the sides of triangles extending over the whole of the ground; the lengths of those sides are determined by admeasurement, and in places where they do not coincide with the roads, hedges, &c., offsets are measured from the sides to the principal bends in those boundaries. In order to "plot" the survey in this case, a proper scale of graduations, usually representing "chains" and "links," is chosen, and the length of one of the station-lines taken from the scale being laid down on the paper as a base, from the two extremities of it as centres, with distances (taken from the scale) equal to the measured lengths of the two sides, which with the base form the first triangle, arcs are described to intersect one another; this intersection being joined to the extremities of the base by lines, the first triangle is constructed. Each side of this triangle is then used as a base on which another triangle is constructed with lines taken from the scale equal to the measured lengths of the sides, and so on. After the triangulation is thus formed, the offsets are laid down from them. This part of the process is accomplished by setting out with compasses upon each station-line, from one of its extremities, the several distances (taken from the scale) of the points at which the offsets were measured, drawing lines perpendicularly to the station-line at these points, and on them placing, from the scale, the measured lengths of the offsets: lines joining the extremities of these offset lines, either drawn by hand or with a ruler, will represent the lines of roads, the boundaries of fields, and the like. In order to facilitate the operation of laying down the offsets from the station-lines, the surveyor is usually provided with ivory scales graduated to represent chains and links on the edges; by laying an edge of such scale along the station-line, with the zero of the graduations at one end, the several distances of the offset-lines from that extremity can be marked on the line in succession; the scale may then be applied to each offset-line, and the measured extent marked by means of the graduations.

But plotting scales are frequently made with graduations along the edges, and with a short scale, also graduated on an edge, which is disposed at right angles to the length of the principal scale, and is capable of being moved to any part of that scale by having one of its extremities cut so as to slide in a groove formed in the direction of the length of the scale. The perpendicular scale is moved along the principal scale to the graduation which denotes the place of the offset, and the length of the latter is then marked by the graduations on the perpendicular scale. Since the offsets frequently occur on both sides of the station-line, the zero of the graduations on the perpendicular scale may be at some distance from the edge of the principal scale, which is then placed, not in coincidence with the station-line, but parallel to it at such a distance that the zero may always be in that line. By this contrivance, which was first proposed by Major Robe, the offsets from the line may be marked, whether they be above or below it, without displacing the principal scale. To find a convenient scale for plotting a survey, the length and breadth of the whole may be computed approximatively in order to ascertain the number of chains in such length or breadth, and then the dimensions of the paper in inches being known, the number of chains in each inch may be formed by proportion. Plans of estates are usually made from scales of 2, 3, or 4 chains in an inch, and the linear dimensions, on a plan made from a scale of 3 chains in an inch, are equal to $\frac{1}{2376}$ of the actual dimensions on the ground.

In important surveys, where the process consists in measuring a base-line, and observing with a theodolite the three angles of every triangle, the base is laid down on the paper from some scale as before; and at each of its extremities all the angles contained between the base-line and visual rays from different objects to that extremity are set out by means of a protractor. The intersections of the several lines from the opposite extremities of the base determine the positions of the objects, and form with the base the first triangles. The sides of these triangles become then the bases of other triangles, and the angles observed at the extremities of their sides must be set out by the protractor. If any of these lines should have been measured by the chain on the ground, the construction of the triangles by means of the angles may be verified by measuring the lengths of such lines on the scale by which the base-line was laid down. Offsets may also be laid down as already described.

But the practice in ordinary surveys is to observe by the "back angle," as before described, the bearings which the different station-lines make with the meridian-line passing through one of the stations, and to measure with the chain the length of each station-line. These bearings and lengths, together with the offsets, are registered in the field-book, and they are generally transferred to the paper in the following manner:—

A line, as N S, is drawn in any convenient part of the paper, generally in a direction parallel to the right and left sides, to represent the magnetic meridian; and any point Z is chosen in it, at which the centre of the protractor is placed. Then the bearings, or angles made with the magnetic meridian by the different station-lines, H K, K C, C L, &c., are set out by the graduations of the protractor about the point so chosen, and lines, as Z 1, Z 2, Z 3, &c., are drawn from this point through the mark made on the paper on setting out each angle. These lines are so numbered in order to indicate the particular station at which each angle was observed. Then if the assumed point Z on the meridian-line should be the place of the first station, the first line so drawn is in the direction of the first station-line; but if the assumed point is not the first station, the place of this first station must be chosen on the paper, as at H; and a line drawn through it, parallel to Z 1, will be the direction of the first station-line. Its extremity K, found by setting out its length from the plotting scale, will be the place of the second station. Through K a line is to be drawn parallel to Z 2, and this will be the direction of the second station-line, whose length K C must then be set out as before. This process is to be continued till all the station-lines have been laid down; when, if the survey should have been carried round the boundaries of a tract of ground, the second extremity of the last station-line will, provided the operations have been accurately performed, coincide with H, the place of the first station. From these lines the offsets must be set out as before described.

In order to set out the allotments of land in countries which, like some parts of North America, are covered with wood, the surveyor determines on the ground the position of a boundary-line comprehending an area of a square form, each side of which is six or eight miles in length. One of these spaces, which constitutes a township, is usually divided into squares of one mile on each side; and again, these are divided into squares of half or a quarter of a mile on each side.

The boundary-line of the township is determined by measuring with a chain a base-line six or eight miles in length, generally along one side of a square already marked out for some previous township; and at each extremity of this line carrying out one of equal length perpendicularly to the base. A line joining the farthest extremities of the last lines completes the square. In order to mark out the two sides which are perpendicular to the measured base, a circumferentor, or a large surveying-compass, furnished with plain "sights," and mounted on a stand, is used. The bearing of the intended line from the magnetic meridian being ascertained from the position of the base, and the instrument being set up at one extremity of that line, the line of the sights is turned so as to make with the needle of the compass an angle equal to that bearing; then the surveyor, looking in the direction of the sights, observes some remarkable tree, and causes the distance from his station to that tree to be measured, small trees, if such there be between himself and the object, being cut down. Notches are cut in the tree in order that it may be distinguished from the others, and the instrument is removed to the opposite side of the tree. The line of the sights is then turned so as to make the given angle with the needle, and the distance of the station to the next remarkable tree in the line is measured as before. This process is continued to the extremity of the line which is to be set out, and strong stakes are planted at the end of each mile, half mile, and quarter mile on the line. From these stakes the lines of division and subdivision are carried out in a similar manner.

When the allotments are contiguous to a road, or the bank of a river, a narrow front is measured along the road or river, and the boundary-lines are carried out, perpendicularly to the front, as far as may be requisite in order to comprehend between them the intended area.

SURVIVORSHIP. A question of life contingencies is said to be one of survivorship when a benefit depends upon the order of the deaths of individuals in such manner that it shall be necessary to calculate the chance of one individual dying before another in every year of life. This distinctive name depends therefore entirely upon the mathematical character of the problem, and of two questions, which both seem to depend on survivorship in the common sense of the word, one may really do so, in the technical sense, and not the other. Thus the question of finding the premium of an assurance on the death of A, provided B die first, is one of survivorship: but that of finding the value of an annuity on the life of A, to begin at the death of B, is not.

The *chance of survivorship* is that of one individual, now of a given age, surviving another, also now of a given age. The following table exhibits the chance of the older life surviving the younger, according to the Carlisle Table. Thus the chance that 65 shall survive 25 is ·110; consequently the chance of 25 surviving 65 is 1 − ·110 or ·890; and it is 890 to 110, or about 8 to 1, that of two persons aged 65 and 25, the elder shall die first.

Elder.	Younger.	Chance of elder surviving younger.
15	5	·400
20	10	·383
25	15	·381
30	20	·375
35	25	·372
40	30	·366
45	35	·360
50	40	·350
55	45	·329
60	50	·315
65	55	·323
70	60	·322
75	65	·303
80	70	·320
85	75	·332
90	80	·329
95	85	·462
25	5	·307
30	10	·283
35	15	·279
40	20	·270
45	25	·263
50	30	·251
55	35	·231
60	40	·213
65	45	·194
70	50	·177
75	55	·177
80	60	·190
85	65	·174
90	70	·191
95	75	·200
35	5	·235
40	10	·207
45	15	·203
50	20	·189
55	25	·174
60	30	·158
65	35	·143
70	40	·126
75	45	·104
80	50	·093
85	55	·094
90	60	·113
95	65	·147
45	5	·177
50	10	·146
55	15	·135
60	20	·119
65	25	·110
70	30	·097
75	35	·081
80	40	·075
85	45	·059
90	50	·052
95	55	·078
55	5	·125
60	10	·091
65	15	·085
70	20	·071
75	25	·061
80	30	·056
85	35	·046
90	40	·044
95	45	·049
65	5	·086
70	10	·054
75	15	·048
80	20	·040
85	25	·034
90	30	·035
95	35	·039
75	5	·057
80	10	·028
85	15	·024
90	20	·013
95	25	·029
85	5	·040
90	10	·017
95	15	·023
95	5	·036

SURVIVORSHIP. [JOINT TENANCY.]

SUSPENSION is a term used in law when a seignory, rent or other profit out of land, by reason of the unity of possession of the seignory, rent, &c., and of the land out of which they issue, are not *in esse* for a time, but may be revived or awaked. It differs from extinguishment, which is when the rent, &c., is gone for ever by reason of the estate in the land being coextensive with that in the rent, &c. (Co. Litt., 313, *a*.)

SUSPENSION BRIDGE. [BRIDGE, col. 354, &c.]

SUSPENSION, CENTRE OF. [CENTRE, col. 734.]

SUSPENSION, ECCLESIASTICAL, is a mode of censure or secondary punishment inflicted by the church on persons guilty of those minor offences which do not deserve the severer penalties of deprivation or excommunication. "In the laws of the church," says Bishop Gibson, "we read of two sorts of suspension—one relating solely to the clergy, the other extending also to the laity."

"That which relates solely to the clergy is suspension *ab officio et beneficio* (that is, the duties and income of his office) jointly, or *ab officio* or *beneficio* singly, and may be called a temporary degradation or deprivation, or both." "The other, which relates to the laity also, is suspension, *ab ingressu ecclesiæ* (that is, from entering the church), or from the hearing of divine service and receiving the holy sacrament, which may therefore be called a *temporary excommunication*." He also observes that the two sorts of suspension agree in this, that both are inflicted for crimes of an *inferior* nature; that both, in *practice* at least, are temporary; and lastly, both, if unduly performed, are attended with further penalties. (See Gibs., 'Cod.,' tit. xlvi., cap. 3.)

In the Roman Catholic Church various kinds of suspension were inflicted for a great variety of offences. A few may be mentioned to illustrate the nature of this punishment. A bishop might be suspended from wearing the sacred vestments of his order, or from exercising his power of collating, instituting, or presenting to livings, or from the exercise of his jurisdiction, or from his office and benefice, or even from entering the church. These various species of punishment were inflicted for such offences as delaying to consecrate a church after proper application, not punishing concubinary priests, or corrupt and irregular practices in instituting persons to ecclesiastical preferments. The inferior orders of the clergy and other religious persons might be suspended from their office or benefice, or from performing service, or from receiving the sacrament, or from entering the church. The offences so punished were delay or irregularity in the performance of their duties, not wearing a proper dress, violating the rules of their order with respect to eating and drinking, neglecting to receive the sacrament at Easter, or extortion.

Suspension was either imposed by sentence after trial, in which case it must have been preceded by admonition, or was ipso facto upon the perpetration of certain crimes. (Gibs., 'Cod.,' *ubi supra*.)

Suspension has been retained as a mode of punishment in the English church. By the 33rd canon of 1603, a bishop ordaining a person who has not a proper title, and refusing to maintain him till he prefer him to some ecclesiastical living, is to be suspended from giving orders during one year: by the 35th canon, a bishop admitting to sacred orders any one not properly qualified is to be suspended from making either deacons or priests during two years; and by the 36th canon, a bishop ordaining any one who has not subscribed in the manner required by that canon is to be suspended from giving orders during twelve months.

It is also declared by the 68th canon that a minister refusing to christen or to bury shall, except under circumstances particularly specified by the canon, be suspended by the bishop of his diocese from his ministry by the space of three months.

The above are the principal cases in which suspension still exists as a form of punishment in the church of England. With respect to the laity, this censure is now entirely disused.

SUTTEE (*Sati*, from the Sanskrit *sat*, good) properly means a chaste and virtuous wife, and in ordinary use is applied to one who burns herself on her husband's funeral pile. The term has been employed by Europeans to denote the act of self-immolation as practised by Hindu widows. When this practice was first introduced cannot be determined with any degree of certainty: it is described by the Greek writers of the age of Alexander, and by Mohammedan and Christian travellers of the 16th and 17th centuries. Diodorus (xix. 33) gives an instance of a suttee which occurred in the army of Eumenes upwards of 300 years before the Christian era; and he ascribes the zeal for this kind of self-sacrifice, in most instances, to the infamy which attached to those widows who refused to conform to the custom. This is also the view taken by our missionaries; but as Elphinstone ('History of India,' i.) justly observes, if the motive were one of so general an influence, the practice would scarcely be so rare. It is not improbable that the doctrine of transmigration generally held throughout India may have had some influence in the establishment of the custom of the suttee. A widow, by burning herself with the corpse of her husband, was to be immediately released from further migration, and enter at once on the enjoyments of Heaven, to which by this act she would also entitle the deceased. Again, perhaps the hope of meeting the departed in the Swarga (Sahagamana) would be sufficient to induce a faithful wife to sacrifice herself. But, however ancient, there are in fact no authentic ancient writings of India, whether legal or religious, which make any mention of it. It is certain that Manu, in his directions to Hindu widows (book v.), does not even allude to it. It cannot be denied, however, that some good Indian authorities recommend the practice, but by no means command it. According to a summary of the law and custom of Hindu castes, compiled by Arthur Steele, and printed at Bombay by order of the governor in 1827, the most virtuous mode of becoming a suttee is to die of affliction and grief on the husband's death. The usual practice, indeed, is self-immolation on the husband's funeral pile; but the many cases under which a widow is excused becoming a suttee, strongly support the supposition that none of the Hindu law-books imperatively command it. The success which has attended the attempts of the British government to abolish the suttee, is a sufficient proof that the natives themselves were not so averse to its suppression as had been expected. In 1826 the government declared the burning of a widow without the body of the deceased (*anumarana*), and under various other specified circumstances, illegal; and all persons, whether relations or others, aiding or abetting in such an act, either before or after the death of the husband, were to be committed for trial at the circuit courts, and were made liable to the punishments for murder and homicide. It was, however, not until 1829 that a regulation was passed, on the 14th December, by the governor-general, Lord W. Bentinck, in council, declaring the practice of suttee, or of burning or burying alive the widows of Hindus, with or without the body of the deceased (*anumarana* or *sahamarana*), to be illegal and punishable by the criminal courts. The practice is still retained in some of the independent governments of India, but is much less prevalent since its abolition in the English territories.

The mode of burning was the same throughout India, varying only according to the rank of the deceased or the province where it was performed. The accounts of all Eastern travellers abound with instances of suttees: it will be sufficient here to give a short sketch of the ceremony. The husband is directed by the physician, when there are no hopes of his recovery, to be carried to the river side, and the wife then breaks a small branch from the mango-tree, takes it with her, and proceeds to the body, where she sits down. The barber paints the sides of her feet red, after which she bathes, and puts on new clothes. During these preparations the drum beats a certain sound, by which it is known that a widow is about to be burnt with the corpse of her husband. On hearing this, all the village assembles. The son, or, if there be no son, a relation, or the head man of the village, provides the articles necessary for the ceremony. A hole is dug in the ground, round which stakes are driven into the earth, and thick green stakes laid across to form a kind of bed, upon which are laid abundance of dry faggots, hemp, clarified butter, and other combustibles. The widow now presents her ornaments to her friends, ties some red cotton on both wrists, puts two new combs in her hair, paints her forehead, and puts some parched rice and cowries into the end of the cloth which she wears. While this is going forward, the dead body is anointed with clarified butter and bathed, prayers are repeated over it, and it is dressed in new clothes. Ropes and another piece of cloth are spread upon the pile. The widow walks seven times round the funeral pile, strewing parched rice and cowries, and then she ascends the pile, or rather throws herself upon it.

(Ward's *Hindoos*, ii. 90; Elphinstone, *History of India; Parliamentary Papers on Suttee;* Sir John Malcolm's *Memoir of Central India.*)

SUTURE, in Surgery, is the method of sewing together the edges of wounds; and the term is also applied to the threads with which the operation is effected.

The only wounds in which the application of sutures can be beneficial are those of which the edges, if held together, are likely to unite. They are therefore improper in all contused wounds, in the majority of lacerations, and in those wounds which extend so deep that, though the superficial parts might be brought together, the deep ones would remain open. But in cleanly-cut wounds, whose edges can be placed and kept in contact without any painful stretching of the parts adjacent to them, sutures are, if applied with proper cautions, by far the most convenient and secure method of obtaining a speedy reunion.

The necessary cautions are, that they should not be allowed to remain in the wound till they excite acute inflammation, and that if from any cause the wound become inflamed, they should be at once removed. In general, thirty-six hours are sufficient for a wound through the skin and the superficial parts to unite so far that it does not need sutures to keep its edges in contact. After this time, therefore, the sutures should be removed; and in cases of deeper wounds, and of amputations, it will not be necessary to retain them more than twenty-four hours longer.

The several kinds of suture employed in surgery are named the interrupted, the uninterrupted, and the twisted. In the first, the edges of the wound, having been duly cleaned, are brought together by several single stitches placed an inch or more part. A threaded curved needle is passed through the skin from one side of the wound to the other, so as to include about one-third of an inch of healthy skin on each side of it, and then, the needle being cut off, the two ends of the thread are tied pretty firmly in a double knot over the line of the wound. This is repeated as many times as the length of the wound requires, and the spaces between the successive sutures, where the edges of the wound usually gape a little, may be held together by sticking-plaster. The latter alone will suffice when the sutures are removed.

In the uninterrupted or glover's suture, a single thread is carried alternately from one side to the other along the whole length of the wound, the needle being in each stitch passed from the border of the wound towards the adjacent healthy skin. There are only two kinds of cases in which this mode of suture can be usefully employed, namely—first, in certain wounds of the stomach and intestines, when those organs are to be returned into the abdomen, and it is of the highest importance that every part of the opening into them should be closed, so that their contents may not escape; and secondly, in ordinary cuts of the palm of the hand or the fingers, where, the cuticle being thick, the uninterrupted suture may be made without pain.

The twisted suture is employed for wounds in those parts of the skin which are very loose, and in which it is desirable to obtain a very exact union by the first intention, such as the lips, the eye-lids, the cheeks, &c. Instead of threads, one or more pins are passed across the wound and through the adjacent skin; and the edges of the former being brought together, are retained in their places by coils of silk wound like the figure 8 upon the projecting ends of the pins. This is the mode of suture commonly employed after the operation for hare-lip. [HARE-LIP.]

With all kinds of sutures it is of the highest importance that the dressings over them should be very light and cool. It is probably owing to the neglect of this caution, and of that already given respecting the time during which they should be retained, that some surgeons have been led to regard sutures as more mischievous than beneficial, ascribing to them the injuries produced by the injudicious management of other parts of the treatment.

SWAN. In England the swan is said to be a bird royal, in which when at large in a public river or creek, no subject can have property, except by grant from the crown. In creating this privilege the crown grants a swan-mark (cygninota), for a *game* of swans, called in law Latin deductus (a pastime, un déduit) cygnorum, sometimes volatus cygnorum. (7 Coke's 'Rep.,' 17.) In the reign of Elizabeth, upwards of 900 corporations and individuals had their distinct swan-marks, some of which may be seen in Yarrell's 'British Birds,' vol. iii., 121, &c.

Sometimes, though rarely, the crown, instead of granting a swan-mark, confers the still greater privilege of enjoying the prerogative right (within a certain district) of seizing white swans not marked. Thus the abbot of Abbotsbury in Dorsetshire had a game of wild swans in the estuary formed by the Isle of Portland and the Chesil Bank. The swannery at Abbotsbury is the largest in the kingdom; though formerly considerably more extensive, it still numbers many hundreds of these birds. It is now vested in the earl of Ilchester, to whose ancestor it was granted on the dissolution of the monasteries. (7 Co. 'Rep.,' 17; Hutchins, 'Dorset,' i. 538.)

The privilege of having a swan-mark, or game of swans, is a freehold of inheritance, and may be granted over. But by 22 Edw. IV., c. 6, no person, other than the king's sons, shall have a swan-mark, or game of swans, unless he have freehold lands or tenements of the clear yearly value of five marks (3*l.* 6*s.* 8*d.*), on pain of forfeiture of the swans, one moiety to the king, and the other to any qualified person who makes the seizure. In the first year of Richard III. the inhabitants of Crowland in Lincolnshire were exempted from the operation of this act upon their petition setting forth that their town stood "all in marsh and fen," and that they had great games of swans, "by which the greatest part of their relief and living had been sustained." (6 'Rot. Parl.,' 260.)

Two of the London Companies have games of swans, the Dyers' and the Vintners' Company, and are, with the crown, the principal owners of swans in the Thames. The swan-mark of the Dyers' Company is a notch, called a "nick," on one side of the beak. The swans of the Vintners' Company, being notched or nicked on each side of the beak, are called "swans with two *nicks*," whence by corruption the term which has been long used as a sign by one of the large inns in London, "swan with two necks."

On the first Monday in August in every year the swan-markers of the crown and the two Companies of the city of London used to go up the river for the purpose of inspecting and taking an account of the swans belonging to their respective employers, and marking the young birds. In ancient documents this annual expedition is called swan-*upping*, and the persons employed are denominated swan-*uppers*. These are still the designations used amongst the initiated, though popularly corrupted into swan-*hopping* and swan-*hoppers*.

The king had formerly a swanherd (magister deductus cygnorum, 'Rot. Parl.,' 16 R. II.; 4 'Inst.' 280) not only on the Thames (6 'Rot. Parl.,' 1 H. VII., fo. 359), but in several other parts of the kingdom ('Abb. Rot. Original.,' 266 b; 'Cal. Rot. Pat.,' 174 a).

Stealing swans marked and pinioned, or unmarked, if kept in a mote, pond, or private river, and reduced to tameness, is felony. (Hale, 'Pleas of the Crown,' 68.) Stealing swans not so marked or so kept, or so pursued, is merely a trespass or misdemeanor. (Dalton's 'Justice,' c. 156.)

Under the 11 Henry VII., c. 17, stealing the eggs of swans out of their nests was punished by imprisonment for a year, and a fine at the king's pleasure. But this enactment was superseded by the 1 Jac. I., c. 27, § 2, which declares that every person taking eggs of swans out of their nests, or wilfully breaking or spoiling them, may upon conviction before two justices be committed to jail for three months, unless he pay to the churchwardens for the use of the poor 20*s.* for every egg; or, after one month of his commitment, become bound, with two sureties in 20*l.* a-piece, never to offend again in like manner. And see 'Calend. Rot. Pat.,' 153 b, 165 b, 166 a, 168 a.

The 2 Henry IV., c. 21, which directs that no lord shall give any livery or sign to any knight, esquire, or yeoman, contains a proviso, that the prince may give his honourable livery of the *Swan* to his lords, and to gentlemen his menials. (3 'Rot. Parl.,' 478 a.)

(See Blomfield's *Norfolk;* Kemp's *Losely MSS.;* *Archæologia*, vol. xvi.; Colonel Hawker.)

SWEARING, a profane use of the name of the Deity. By the 109th canon, churchwardens are to present those who offend their brethren by swearing, and notorious offenders are not to be admitted to communion until they are reformed. Profane cursing and swearing were first made an offence punishable by law by 20 J. I., c. 21 (continued by 3 Ch. I., c. 4; 16 Ch. I., c. 4; and 6 & 7 W. III., c. 11). By the 19 G. II. c. 21, it is recited that these vices were become so frequent, that "unless speedily and effectually punished, they may justly provoke the divine vengeance to increase the many calamities these nations now labour under," and the statute accordingly enacts that if any person shall profanely curse or swear, and be convicted thereof on confession, or on the oath of one witness, before any magistrate, he shall forfeit, if a day-labourer, common soldier, sailor, or seaman, 1*s.*; if any other person under the degree of gentleman, 2*s.*; if of or above the degree of a gentleman, 5*s.*; for every second conviction double, and for every third and subsequent conviction treble. The penalties are to go to the poor of the parish. If the offence is committed in the hearing of the magistrate, he may convict without further proof. Parties who do not pay the penalties and costs may be imprisoned and kept to hard labour ten days for the penalties, and six other days for the costs. Magistrates and constables are liable to penalties if they wilfully omit to do their duty under the act. No person can be prosecuted except within eight days after he has committed the offence.

SWEATING-SICKNESS. *Ephemera Sudatoria, Ephemera Maligna, Sudor Anglicus, Hydronosus*, are the various names which have been given to a severe epidemic disease that prevailed in this country and in some parts of the Continent at different periods during the latter part of the 15th and the beginning of the 16th centuries. The invasion of this disease was generally quite sudden, some persons experiencing a sensation as of a hot vapour extending over the body, while others felt as if consumed by an internal fire; there was violent fever, pain in the head and limbs, prostration of strength, hurried breathing, a small frequent pulse, nausea, great thirst, delirium, and excessive restlessness. Shortly after the appearance of these symptoms a profuse clammy fetid perspiration broke out over the whole body; the thirst became more intolerable, and the patients either died in a state of delirium or coma, or recovered as suddenly as they had been first attacked. Such was the rapidity with which this disease ran its course, that its victims were sometimes carried off in three or four hours, or even before the sweating stage had set in; and all danger was considered to be at an end if the patient survived the first twenty-four hours. The profuse sweating which characterised the disease was looked upon as an effort of nature to get rid of some morbific matter from the system, and the early appearance of this stage was, therefore, regarded as a favourable circumstance. Accordingly, when persons were attacked, it was usual to put them immediately to bed, without even removing their clothes, to enjoin absolute quietude, and to encourage the outbreak of the perspiration by heating the room, covering them well up from the air, and giving them mild cordials. If the sweating stage were tardy in appearing under the influence of these means, friction was had recourse to; and if the patient were at the same time very feeble, drinks of a more stimulating quality were administered: fumigations with storax, laurel, or juniper berries were also employed. These remedies were persisted in till the sweating was fully established. After twelve or fifteen hours the coverings of the patient were diminished, the apartment was made cooler, and the air was impregnated with the vapour of vinegar; sleeping was not allowed at this stage of the complaint unless the pulse was strong, it having been observed that those who indulged in this propensity seldom woke again. At the end of twenty-four hours the linen was all changed, nourishing food was gradually administered; and on the second or third day, if the weather was propitious, the patients were allowed to go out. This mode of treatment, which is so different from that pursued in the present day in analogous diseases, does not appear to have been adopted simply with the view of hastening the accession of the sweating stage, but from the experience of the injurious influence of cold in this disease, several fatal cases having been attributed to the mere exposure of the patient's arms to the air while in bed.

The sweating-sickness is said to have made its first appearance in this country in the army of the earl of Richmond, on his landing at Milford Haven in the year 1485. On the 21st of September of the same year it reached London, where it raged till the latter end of October. It reappeared in this country during the summers of 1506, 1517, 1528, and 1551. From 1525 to 1530 it visited Holland, Germany, Denmark, Sweden, Poland, and parts of Russia; and Forestus informs us (lib. vi., obs. 8) that it broke out in Amsterdam on the 27th of September, 1529, where it raged but four days, sparing only old people and children, and attacking above one hundred persons a day. With respect to the mortality of this disease accounts are somewhat vague. Bacon informs us that in the first epidemic the patients recovered if they were attended to in time, but that many died before a remedy was discovered. The epidemic of 1517 appears to have been particularly fatal, frequently destroying its victims in two or three hours, and in some places carrying off one-third, and even one-half of the inhabitants: that of 1528 was also very fatal, but was remarkable for its short duration in each place. The last outbreak of this disease in England happened at Shrewsbury in the year 1551, and was extremely fatal, sparing neither age nor sex: it raged from April to September, becoming milder in character towards its termination.

The origin and causes of this singular malady are still involved in considerable mystery. Bacon speaks of it as a terrible and unknown disease, that had its origin neither in the blood nor in the humours; a surprise of nature, rather than obstinate to remedies. Drs. Caius and Mead believed it to be a modification of the plague; and Dr. Mead says that it was imported into this country from France, whither it had been conveyed in 1480, from the island of Rhodes, at that time besieged by the Turks. Caius affirms that the two epidemics of 1517 and 1528 were brought to England from Florence and Naples, at which places the plague was then raging, and that it was the same disease, only modified by climate. Dr. Cullen thought it a variety of typhus; and Dr. Willan suggested that it might have been produced by some disease in the wheat at those periods at which it prevailed, just as the Asiatic or malignant cholera has been attributed to the eating of bad rice. Opinions are not less at variance respecting the antiquity of this disease, and its identity with that which still prevails on some parts of the Continent, to which the term of "La Suette" has been applied. M. Rayer, without giving a decided opinion on the subject, admits that although there are notable differences between the two diseases in point of duration and gravity, yet there is an incontestible analogy between them. It is perhaps impossible at this distance of time to decide the question: we shall therefore conclude this article by referring those who may feel an interest in the subject to M. Rayer's 'Histoire de l'Epidémie de la Suette-Miliare qui a régné en 1821, dans les Départemens de l'Oise et de Seine-et-Oise,' 8vo., Paris, 1822.

SWELL. [Organ.]

SWIFTEST PROPAGATION. [Undulatory Theory.]

SWORD MANUFACTURE. Weapons of offence were early fabricated by the cutlers of Sheffield. Holland ('Manufactures in Metal') gives a representation of two men grinding a sword-blade, copied from a manuscript psalter, written about the time of King Stephen, which is preserved in the library of Trinity College, Cambridge, and which probably represents the usual construction of grinding machinery at that time. The grindstone is mounted upon a horizontal axis, which one man turns by means of a crank; and the sword, which is straight and pointed, is pressed down upon its periphery by the other man, who sits on a beam above the level of the stone, so that his weight may be conveniently thrown upon the sword, to press it firmly against the stone.

But while there can be no doubt of the extensive manufacture of swords in England at an early period, the blades made in Spain and Italy, and more especially those brought from the East, bore the preeminence. The swords of Toledo were sought after on account of their admirable temper, in the time of the Moors, and even under the Romans. It has been supposed that they were indebted for their valuable qualities to some peculiar property in the water of the Tagus, which is used in tempering them. In the early period of the French invasion, the manufactory was removed to Seville, where the national junta then was; but it was found that the swords manufactured on the banks of the Guadalquivir were very inferior to those which the same workmen had made at Toledo. In the time of the crusades, and down to a much later period, Milan supplied swords of excellent quality in large numbers. But, celebrated as these and the Spanish blades deservedly were, those from the East were still more highly prized, and enormous sums were often given for them, Of all the sabres, the fame of which has reached this country, those of Damascus are by far the most noted. Very few persons indeed have seen them; and fewer still have been the instances in which the blades themselves have confirmed those strange stories about their temper which are so generally circulated, and received among persons who know but little of the nature of steel. The characteristics ascribed to the real Damascus blades are, extraordinary keenness of edge, great flexibility of substance, a singular grain and fleckiness observable upon the surface, and a peculiar musky odour given out by any friction of the blade. Their quality, undoubtedly excellent as it must be, has been greatly exaggerated; the extraordinary powers of execution attributed to Damascus blades are, in a great measure, dependent upon the strength and dexterity of the user. A gentleman who purchased one of these sabres in the East Indies for a thousand piastres, informed Mr. Holland that, although it was very flexible, and bore a fine keen edge, it could not be safely bent to more than 45° from a straight line, and it was not nearly so sharp as a razor; yet, when wielded by a skilful hand, it would cut through a thick roll of sail-cloth without apparent difficulty. The swordsman who tried it could, it appears, do nearly the same thing with a good European blade.

About the year 1689 an attempt was made to improve and extend the sword manufacture of England by the incorporation of a company of sword-cutlers for making hollow sword-blades in Cumberland and the adjacent counties. The company was empowered to purchase lands, to erect mills, and to employ a great number of German artificers; yet the project failed. Owing, apparently, to the parsimony of the manufacturers, which led them to use inferior materials, and to employ unskilful workmen, English sword-blades fell into very ill repute during the 18th century. In 1783 the sword-sellers of London, in consequence of the very bad quality of English blades, petitioned the lords of the treasury for permission to import German swords free of duty; and this circumstance, by attracting public attention forcibly to the low state of this branch of British cutlery, led to very important improvements. Mr. Gill, of Birmingham, memorialised the lords of the treasury, stating that he could make sword-blades equal to those of Germany, and requesting a fair comparison. Circumstances delayed the public trial which he desired; but in 1786, the East India Company requiring 10,000 horsemen's swords, divided their orders indiscriminately among English and German manufacturers. Owing to the exertions of Mr. Gill, by whom some of these swords were made, a comparative trial was appointed, and every sword sent in was submitted to a machine recommended by Matthew Boulton, of Soho, in which the metal was tried by forcing the sword into a curve, so as to reduce its length from 36 inches to 29½ inches. The result was that 2650 of Mr. Gill's swords bore the test, and only 4 were rejected, while of the German swords 1400 were received and 28 rejected. The extremely low state of the British sword manufacture at that time is sufficiently testified by the fact that of the blades sent by other English cutlers, 2700 were received and 1084 rejected. In addition to the above-mentioned test, Mr. Gill tried his swords by striking them flatways upon a slab of cast-iron, and edgeways upon a cylinder of wrought-iron, which they often cut through. They were so tough, although formed of cast-steel, that, after cutting a gun-barrel asunder, Gill would frequently wind the blade round it like a riband, after which it would recover its original straightness, excepting at the point. So completely did he establish the fame of his swords, that even German officers applied to him for them.

The process of manufacturing swords at Birmingham is as follows:—The material of which the blade is wrought should be cast-steel of the very best quality, and wrought with the greatest care. The bars are heated in the fire, and drawn out upon an anvil by two workmen with hammers, giving alternate strokes. When the blade is required to be concave upon the sides, or to have a reeded back, or some similar ornament, it is hammered between steel bosses or *swages*. The blade is then hardened by heating it in the fire until it becomes worm-red, and dipping it, point downwards, in a tub of cold water. It is tempered by drawing it through the fire several times until the surface exhibits a bluish oxidation, which takes place at a temperature of about 550° Fahr. The sword is then *set* to the required shape by placing it on a sort of fork upon the anvil, and wrenching it by means of tongs in the direction required to correct any degree of warping which it may have contracted during the hardening. The grinding is performed upon a stone with either a flat or fluted surface, according to the kind of blade; and as the uniformity of the temper is impaired by this process, it is subsequently restored by a slight heating, after which the blade is glazed with emery, and, if the instrument be a fine one, with *crocus martis*, after the manner of a razor-blade. The sword is then ready for the hilt or handle. Among the tests to which sword-blades are subjected, is that of bending them into a curve by pressing the side of the blade against six or eight pegs driven into a board, in such a manner that, when in contact with all the pegs, the middle of the blade may be bent six or seven inches from a straight line drawn between the point and the hilt. A further test is applied by bending them from a vertical pillar rising from a board. The temper is also proved by striking the blade smartly upon a table on both sides, and by severe strokes with the back and edge upon a block. Mr. Inglis, in his 'Spain in 1830,' describes the trials to which sword-blades are subjected at the celebrated manufactory of Toledo. Each sword is thrust against a plate in the wall, and so bent into an arc forming at least three parts of a circle; and then struck edgeways upon a leaden table with all the force which can be given by a powerful man holding it with both hands.

The British cavalry, within a recent period, have been supplied with swords superior in quality to those before in use, slightly different in shape, and lighter in weight.

Many plans have been tried for imitating the peculiar waved appearance of Damascus blades, which is commonly called *damasking*. The Oriental processes have never been satisfatorily described, although several methods have been devised in Europe for imitating the Eastern fabrics. MM. Clouet and Hachette have pointed out three methods of attaining the desired object. The first, which is still pursued by some French cutlers, consists in scooping out with a graving tool the faces of a piece of stuff composed of thin plates of steel of different kinds; and by a subsequent operation filling up the hollows, and bringing them to a level with the external faces, upon which they form a figured appearance. The second is called the method of *torsion*, and is more generally employed. It consists in forming a bundle of strips of steel, which are welded together into a bar, and twisted several times about its axis. It is repeatedly forged and twisted alternately; after which it is slit longitudinally, and the two halves are welded with their outer sides together. The surfaces of such a bar have a curious waved or watered appearance, owing to the inter-twisting of the several rods of which it is composed. The third, or *mosaïc* method, consists in preparing a bar in the way last described, then cutting it into short pieces, and forming them into a faggot; taking care in welding them together to preserve the sections of each piece at the surface of the blade. The experiments published some years since at Milan, by Professor Crivelli, show that sword-blades of excellent quality may be produced by a combination of iron and steel. A bar of malleable steel, about an inch and a half in breadth and one-eighth of an inch in thickness, is bound round with iron-wire, at intervals of one-third of an inch. The iron and steel are then incorporated by welding, and repeated additions of iron-wire are incorporated in the same way. The compound bar thus formed is then stretched and divided into shorter lengths, which are subsequently wrought into the required form, ground, and tempered. By filing semicircular grooves into both sides of the blade, and again subjecting it to the hammer, a beautiful damasked appearance is produced; and the figures or waterings are rendered visible by washing the blades with a menstruum of aquafortis and vinegar, so as to corrode the surface slightly. The process is said to have been practised successfully in Austria and Prussia.

Another way of explaining the variegated appearance of Damascus blades is that of M. Bréant. He supposes that the oriental damask is not a mixture of steel and iron, but simply cast-steel charged with a superabundance of carbon; so that, by slow cooling, two distinct combinations are formed, the first being simply steel, and the second a mixture of steel with the excess of carbon, forming a carburetted steel or cast-iron. These two compounds form a kind of crystallised surface, which, by washing with acidulated water, assumes a damasked appearance; the parts consisting of pure steel becoming black, while the carburetted steel remains white.

Besides the numerous contrivances for producing the variegated appearance of Damascus blades, ingenious processes are resorted to for ornamenting sword-blades by etching and embossing, and by inlaying them with gold and silver wire, an art to which the name of *damascening* is sometimes applied. In the article DAMASCENE WORK, this process is noticed.

SWORDS. *Greek Swords.* The earliest and fullest information on the subject of the Greek swords is in the poems of Homer. With him the *ξίφος*, *ἄορ*, and *φάσγανον* are synonymous terms: the *μάχαιρα* is a large knife suspended near the *ξίφος* ('Il.,' iii. 271) for the purpose of cutting anything; the *ξίφος* is called *μελάνδετον*, a term not very satisfactorily explained, and *ἀργυρόηλον*, or studded with silver, an epithet relating probably to the handle (*κώπη*), which is said to be of silver: the scabbard, *κολεὸς*, in later writers called *θήκη* ('Od.,' viii. 404), is covered with ivory.

At a later period coins, vases, and other ancient monuments, exhibit the form of the Greek sword, which was a short cut-and-thrust blade, diminishing gradually from hilt to point.

Varieties in the form of the blade and handle are occasionally to be met with on vases. (Millin., 'Vases Antiques,' pl. 26 and 56.) The *θήκη*, or scabbard, sometimes terminates in a knob, the *μύκης* probably of Herodotus (iii. 64). We have only scanty and incidental notices of the sword in Greek writers after the time of Homer. C. Nepos ('Iphicrates,' c. i.) records that that general introduced a longer sword among the Athenian infantry. Xenophon ('De Re Eques.,' xii.) prefers the *μάχαιρα* to the *ξίφος* for cavalry, because their position on horseback he considers more favourable for the cutting than thrusting: in this passage *μάχαιρα* is used synonymously with *κοπίς*, which leads us to suppose it to have been made at that time only for cutting. In later writers the terms *μάχαιρα* and *ξίφος* are used indiscriminately. (Polyb., iii. 114.)

The Greek sword was worn on the left side, suspended by a belt generally from the shoulder, as in the figure of Meleager on the coins of Ætolia, but occasionally by a girdle round the waist. On a vase in Millingen (pl. 23) it is slung more forward, so that the hilt is in the middle of the breast. The material of the Greek blade was generally bronze; in later times, iron.

Roman Swords.—The Roman sword was called "ensis," "gladius," and "mucro" (though "mucro" originally meant the point of the sword only; its edge, "acies;" its handle, "capulus;" its scabbard, "vagina"). Polybius gives an accurate description of the Roman sword used in his day, which had the Iberian short straight cut-and-thrust blade of finely tempered steel: this had been substituted for the old Roman sword at the time of the war with Hannibal (lib. vi.; also 'Fragm.,' xiv., where he speaks of the admirable temper of the Celtiberian blades). The form of the sword continued from his time till that of the later emperors, apparently unchanged. Montfaucon ('Antiquités,' vii.) states that the blades of those on the column of Marcus Aurelius and the arch of Severus are more pointed than on the column of Trajan, and that they became shorter in the time of Constantine the Great and Theodosius. Stewechius ('Comment.' in Vegetium, p. 64, Vesal., 1670) speaks of a larger kind of sword, "spatha," under the later emperors. There seems to be no distinction in size or shape between the swords of the infantry and cavalry on Trajan's column and other similar monuments. The sword used by the gladiators was somewhat curved. The Roman sword was worn on the right side. Montfaucon notices three exceptions to this general practice on the arch of Septimius Severus; and the spathæ already mentioned are said to be worn on the left side. The parazonium appears to have been the insigne or sword of office of a military tribune. (Martial, xiv. 29; Raderus, 'Comment.,' in loc.; and Pitisc., 'Lexicon Antiq. Roman.')

Other Ancient Swords—For the swords of other nations of antiquity, see Wilkinson's 'Antient Egyptians;' for the Assyrian, the works of Layard and Botta; for the ἀκινάκης, or Persian sword, and that of other Eastern people, Leake, 'Athens,' ii.; and for the swords of the Gauls, Livy, xxii. 46, and Diodorus, v. 30.

In the British Museum are four ancient bronze swords, three of which have cut-and-thrust blades, varying in length from 10 to 25 inches, and in breadth from 1¼ to 2 inches. Another, considered to be Etruscan, is bound with gold wire round the handle, and is about 13 inches long. In Montfaucon ('Antiq.,' vii.) are engravings of three, two of which, as he states, measured a foot and a half (French), and the other 30 inches in length. In the Museo Borbonico, vol. v., pl. xxxix., is an engraving of one having two rings on its scabbard, which is of wood, covered with plates of metal, and studded with brass; a handle of another is finished with an eagle's head, and other varieties are shown in the same work.

SYLLABLE (συλλαβή). A syllable consists of one or more elementary sounds of a language uttered in one emission of voice. The pronoun *I* is an example of a syllable consisting of but one elementary sound; and the syllable *strange* is an example consisting of several elementary sounds articulated (joined) together. Words which consist of one syllable are termed monosyllabic; those consisting of two are termed dissyllabic; those of three, trisyllabic; and those of more than three are indefinitely termed polysyllabic.

Spoken language is a system of audible signs for the expression of thought, and written language is a system of signs to express spoken language, so that written language is two removes from thought. Syllables, both as words and as parts of words, belong both to spoken and written language.

In a pronounced syllable two distinct things are observable, namely, 1st, its elementary structure; and, 2nd, the musical properties of the voice, consisting of those distinctions of sound which are described under the general terms pitch, loudness, and quality. Thus in the pronoun *I* we observe the elementary structure to be the diphthongal vowel *I*, as heard in the word *isle*; and we observe also whether the syllable be said or sung, that is, whether the condition of voice belongs to speech or to song: an accurate observer also perceives the precise degree of pitch and loudness and the character of the quality of voice.

The time which a syllable occupies in pronunciation is termed its quantity. In solemn and stately discourse the quantities of syllables are extended beyond their ordinary length; while in rapid colloquy they are somewhat shortened. The ordinary quantity of a syllable, when neither extended nor protracted, is the sum total of the quantities of its constituent elementary sounds: thus the quantity of the syllable *nine* is the sum total of the quantities of its elementary sounds *n*, *i*, of *isle*, and *n*.

In words of more than one syllable, one of them is always made more conspicuous to the ear than the other, by what is termed stress or accent. Stress is produced either by an abrupt percussion of voice, as in the word *pepper*, or by an extended quantity on a swelling loudness of voice, as in the word *amaze*. The stressed syllable of a word is invariably that which receives the modification of voice expressive of sense and feeling, called emphasis.

The metrical arrangement of language depends on the quantity and stress of syllables, both of which are inherent; while the pitch, loudness, and quality of voice in which the syllables are uttered are accidental, and belong to the thought and feeling of the speaker.

Dividing words into syllables is a different operation according to the object in view, thus: 1. When a word is pronounced in widely separated syllables, to enable a child to appreciate each, as in uttering the word *provided*, thus, *pro-vi-ded*, by which means a child readily apprehends each successive syllable of the word; 2. When a word is analysed into its component parts, in order to exhibit its etymology, and thus lead to a clear apprehension of its signification, as a whole from knowing that of its parts, as in dividing the word *thermometer*, thus, *thermo-meter*; 3. To divide a word into its syllables, to enable another to write it with correctness, as the word *barometer*, thus, *ba-ro-me-ter*.

SYLLOGISM (συλλογισμος). The object and character of logic are explained under the word ORGANON; the position of this article in the present work is explained in LOGIC. Every sentence in which different assertions are combined to produce another and a final assertion, is either a syllogism, a collection of syllogisms, or a mass of words without meaning; and when we separate the constituent assertions, and write the whole under the forms of logic, we are not thereby ceasing to consider the sentence which contains those assertions, or, as many fancy, dealing with a new species of ratiocination. All that is called reasoning, and which cannot be made syllogistic, is not reasoning at all; and all which cannot easily be made syllogistic, is obscure; for the syllogism is the simple form in which the act of reasoning is an act of intuition.

Aristotle defines syllogism thus: "Syllogism is speech or language in which certain things being assumed, something different from what is assumed results by virtue of the assumption; and, by virtue of the assumption, I mean it results through the assumption; and, by 'through the assumption' I mean that no external term is required in order to there being a necessary result." ('Analyt. Prior.' i. 1.)

So easy indeed is the deduction, when the premises are properly disposed as preparatory to a syllogism, that many persons doubt the utility of the syllogism altogether. With these we are not now arguing; we shall only observe that he must be fortunate in the clearness of his mind, who, knowing the logical mode, is never obliged to have recourse to it to destroy ambiguity or heighten evidence; and particularly so in his opponents, who, in verbal or written controversy, never finds it necessary to employ it in trying their arguments. The syllogism is the instrument of self-examination, and the weapon of last resort in dispute; and a bad syllogism, with one of the premises implied only, and not expressed, is the first resource of fallacy; which last is sometimes even allowed to remain unrefuted, by neglect of placing it in a logical form. To bring forward the suppressed premiss is the visible destruction of every such argument which is logically bad. As an instance, take the following in a letter from Cardan to Tartalea: "Neither am I moved with envy, *for* if you are either equal to, or less than myself, I have no cause for it; and, if you be greater in this art, I ought to endeavour to equal you, and not to speak evil of you." This is meant for reasoning, and there are two syllogisms with suppressed premises, or rather two sorites (a term presently explained), with a suppressed premiss in each. In one case Cardan assumes that he does not envy Tartalea because he *need* not; in the other, that he does not because he *ought* to do otherwise: if he meant to assume and assert that he never did anything which he had no need to do, and always did everything which he ought to do, his reasoning is logical; but if he would have hesitated to make these assertions, he was then writing fallacy. In justice to Cardan's logic, however, it is but fair to say, that he was not the man to hesitate at either assertion. [CARDAN, in BIOG. DIV.]

Every sentence in which the conclusion is a necessary consequence of previous assertions contained in that same sentence, is a syllogism, provided that the conclusion be obtained from two distinct assertions, and two only. Thus, "Some As are Bs, for every B is A,' is not a syllogism, though logically true. [CONVERSE.] Every assertion may be reduced to one of four forms, the universal affirmative, the universal negative, the particular affirmative, and the particular negative. From these, by combination, all syllogisms are derived; and the laws of combination, and the manner of expressing them, constituted that branch of science which is now often turned into ridicule, particularly as to its notation, and the strange and uncouth words by which the species of syllogisms were denoted. The following letters always signify the several species of propositions:—

A, the universal affirmative; every X is Y.
E, the universal negative; no X is Y.
I, the particular affirmative; some Xs are Ys.
O, the particular negative; some Xs are not Ys.

Since every conclusion must be drawn from the comparison of two things with a third, a syllogism consists of two propositions, in each of which the same term occurs compared with another: this term is called the *middle term*. Thus, in

Every Y is X,
Every Z is Y,
Therefore Every Z is X,

Y, the subject of the first assertion, and the predicate of the second, is the middle term. The two first assertions are the *premises*, the third is the *conclusion*. The predicate of the conclusion is called the *major term*; the subject of the conclusion the *minor term*: and the major or minor premiss is that which contains the major or minor term of the conclusion. The major premiss is always written first.

The order of the terms in the premises and conclusion must be either

I.	II.	III.	IV.
YX	XY	YX	XY
ZY	ZY	YZ	YZ
ZX	ZX	ZX	ZX;

and these are called the four *figures*. The three first are in Aristotle, the fourth was by tradition ascribed to Galen, and was called Galenic. In the first figure the middle term is the subject of the major, and the predicate of the minor; in the second, the predicate of both; in the third, the subject of both; in the fourth, the predicate of the minor and the subject of the major. Every particular case of a figure is called a *mood*; and since either of the premises may be either of the four species of propositions, A, E, I, O, it follows that there are sixteen moods in each figure, or sixty-four possible moods in all. But of these, many are inconclusive, and many moods which admit of conclusion in one figure do not in another. Thus, the mood in the example above is AA, and if we apply it in the four figures, we have—

Every Y is X	Every X is Y	Every Y is X	Every X is Y
Every Z is Y	Every Z is Y	Every Y is Z	Every Y is Z.

The first has a conclusion: every Z is X. The second has none; that is, for anything to the contrary contained in the premises, we may either say every Z is X, no Z is X, some Zs are Xs, or some Zs are not Xs.

It also admits every X is Z, but here Z is the major term, and not X. The third admits a conclusion: some Zs are Xs. The fourth also admits a conclusion: some Zs are Xs. Consequently, the first figure has a syllogism AAA, the third and fourth have AAI.

If all the sixty-four cases be examined (a most useful exercise), it will be found that the following syllogisms are valid. We arrange them first by figures, then by moods :—

First Figure : AAA, EAE, AII, EIO.
Second Figure : EAE, AEE, EIO, AOO.
Third Figure : AAI, IAI, AII, EAO, OAO, EIO.
Fourth Figure : AAI, AEE, IAI, EAO, EIO.

The following is the statement by moods :—

$(AA)A_1I_3I_4$, $(AE)E_2E_4$, $(AI)I_1I_3$, $(AO)O_2$
$(EA)E_1E_2O_3O_4$, $(EI)O_1O_2O_3O_4$,
$(IA)I_3I_4$,
$(OA)O_3$.

Here, for instance, we express by $(IA)I_3I_4$ that the mood IA never proves anything but I, and that only in the third and fourth figures. From the preceding we may collect that—

As to figures: any proposition may be proved in the first; none but negatives in the second; none but particulars in the third; and everything but the universal affirmative in the fourth.

As to moods: from premises both negative or both particular, no conclusion follows: where one premiss is negative, the conclusion is negative; and where one premiss is particular, the conclusion is particular.

In order to remember the figures certain words have been long used by writers on logic, which make a grotesque appearance; but if the reader will tolerate them till we have gone through an example of each syllogism, he shall see that those who made them were at least as good wits as those who laugh at them. The magic words of the fourth figure are different in different writers; we have taken those used by Dr. Whately.

First Figure : Barbara, Celarent, Darii, Ferio.
Second Figure : Cesare, Camestres, Festino, Baroko.
Third Figure : Darapti, Disamis, Datisi, Felapton, Bokardo, Feriso.
Fourth Figure : Bramantip, Camenes, Dimaris, Fesapo, Fresison.

Thus the vowels AAA are seen in *Barbara*, AII in *Datisi*. The following are instances of each form, with an example which may easily be reduced to the form.

First Figure.

Barbara.—Every Y is X, every Z is Y, therefore every Z is X. *Example.* They must, as men, have faults: or all men have faults, these persons are men, therefore these persons have faults; strictly, all men *are* persons having faults, &c.

Celarent.—No Y is X, every Z is Y, therefore no Z is X. *Example.* Those who bribe should not, any more than any other lawbreakers, be exempt from punishment.

Darii.—Every Y is X, some Zs are Ys, therefore some Zs are Xs. *Example.* Exploded doctrines are sometimes true, because capable of proof.

Ferio.—No Y is X, some Zs are Ys, therefore some Zs are not Xs. *Example.* Some of the earlier principles of science are not well appreciated for want of attention to the usual modes of operation of the mind.

Second Figure.

Cesare.—No X is Y, every Z is Y, therefore no Z is X. *Example.* The presence of horns in this species, and their absence in the other, is a complete distinction between the two.

Camestres.—Every X is Y, no Z is Y, therefore no Z is X. The last example will do: this mood is only a consequence of the convention by which the major premiss is to be written first, and of the convertibility [CONVERSE] of the universal negative proposition.

Festino.—No X is Y, some Zs are Ys, therefore some Zs are not Xs. *Example.* Persons who pretend to form an opinion on philosophical subjects are oftentimes incapable of doing it properly, from want of acquaintance with the exact sciences. This example is given purposely, as falling more naturally into another figure, though capable of expression in this.

Baroko.—Every X is Y, some Zs are not Ys, therefore some Zs are not Xs. *Example.* None but the industrious can succeed, so that there must be many failures.

Third Figure.

Darapti.—Every Y is X, every Y is Z, therefore some Zs are Xs. *Example.* Politics and literature are not necessarily incompatible, for many persons can be named who have cultivated both.

Disamis.—Some Ys are Xs, every Y is Z, therefore some Zs are Xs. *Example.* Many things inexpedient, because wrong, are apparently useful.

Datisi.—Every Y is X, some Ys are Zs, therefore some Zs are Xs. The last example will do for this also.

Felapton.—No Y is X, every Y is Z, therefore some Zs are not Xs. *Example.* There are organised bodies to whose existence air is necessary, and which have no locomotive power, as plants, for instance.

Bokardo.—Some Ys are not Xs, every Y is Z, therefore some Zs are not Xs. *Example.* Even industry does not always succeed, for men of great research have been mistaken.

Feriso.—No Y is X, some Ys are Zs, therefore some Zs are not Xs. *Example.* It is not true that all who gave evidence were present, for A, B, C, &c., were many miles off.

Fourth Figure.

Bramantip.—Every X is Y, every Y is Z, therefore some Zs are Xs. *Example.* Among repulsive things are the sciences themselves, for they are all difficult.

Camenes.—Every X is Y, no Y is Z, therefore no Z is X. *Example.* No perfect being can be man, for all men are subject to decay, the unfailing mark of imperfection. This example would do very well as one of the most common species of fallacy, that in which the middle term is used in different senses, so that there is in fact no middle (or *common* middle) term. We have seen this argument used somewhere, "perfect being" meaning "*morally* perfect being," and "imperfection" including *physical* as well as *moral* imperfection.

Dimaris.—Some Xs are Ys, every Y is Z, therefore some Zs are Xs. *Example.* Some writers who repeat themselves are amusing, for every prolix writer does it, and the most attractive books are not always the shortest.

Fesapo.—No X is Y, every Y is Z, therefore some Zs are not Xs. *Example.* Some things which are not much written about are not worth learning; not that this circumstance is otherwise an index, except in this manner, that all really useful learning has its opponents, and it is only where there is opposition that much discussion ever takes place. Here is a good instance of the case in which the premises both yield the conclusion, and explain the sense in which it is to be taken: the preceding is no syllogism unless the "writing about" the subject in the conclusion mean writing about not the subject itself, but whether it be useful or not.

Fresison.—No X is Y, some Ys are Zs, therefore some Zs are not Xs. *Example.* Some things which are cried up can hardly be relics of antiquity, for they are valueless. Here is an instance of an argument which, logically undeniable, may be disputable as to the *matter*. One of the premises is "no relic of antiquity is valueless," which many may be found to deny.

Some other forms have been given, but they are only some of the preceding with the premises transposed, and which, therefore, do not obey the conventional rule relative to the precedence of the major premiss: as, for instance, one named *Baralipton* (AAI, the last syllable being only a termination) which we may mention particularly, inasmuch as this word has been very often quoted as a specimen of logical terms. It runs as follows:—Every Y is X, every Z is Y, therefore some Xs are Zs. Transpose the premises, and we have the first syllogism of the fourth figure.

Of all the four figures the first is the most natural, and every mood of the other three can be reduced to one of the first, in one of the following ways. It will be seen that every name in the last three figures begins with one of the initial letters of the first, and thus it is pointed out to which mood of the first figure each is reducible. Thus Cesare, Camestres, and Camenes are those which are reducible to Celarent of the first figure.

The other significant letters of the descriptive words are *m*, *s*, *p*, *k*, wherever they occur. By *m* it is implied that the premises are to be transposed; by *s* that the premiss marked by its preceding vowel is to be converted, whence *s* follows only E and I [CONVERSE]; by *p* that the conversion is to be made in a limited manner, or *per accidens* [CONVERSE]; and by *k* that the reduction is made by what is called the *reductio ad impossibile*, a term which we now explain. It means that the syllogism can be replaced by one in the first figure, which proves, not the truth of the conclusion, but the falsehood of its contradictory. [CONTRARY AND CONTRADICTORY.] For example, take the syllogism *Baroko*, or

Every X is Y,
Some Zs are not Ys,
Therefore Some Zs are not Xs.

If the conclusion be denied, it must be by affirming that every Z is X. Let this be so, then we must have the syllogism *Barbara* as follows :—

Every X is Y,
Every Z is X,
Therefore Every Z is Y.

But, by hypothesis, some Zs are not Ys, whence this conclusion contradicts one of the admitted premises, or must be false. One, then, of the premises which gives it must be false; but since Every X is Y is supposed true, it must be Every Z is X, which is false, or Some Zs are not Xs, which is true. This is a specimen of the persevering determination of the older logicians to make everything reducible to the first figure.

It appears then that few words have ever been invented which have really so much meaning as the now despised appellations of syllogisms. Take, for example, *Disamis*; every letter is a sentence. D means that the mood of the first figure into which this can be reduced is Darii; I, that the major premiss is a particular affirmative proposition; S, that the reduction requires the major premiss to be simply converted A, that the minor is a universal affirmative; M, that the reduction requires the transposition of the premises; I, that the conclusion is a particular affirmative; S, that the conclusion must be simply converted. We thus change

DISAMIS. DAR
Some Ys are Xs, ⎫ ⎧ Every Y is Z,
Every Y is Z, ⎬ into ⎨ Some Xs are Ys,
Some Zs are Xs, ⎭ ⎩ Some Xs are Zs.

A *proper* mood was one in which one of the premises spoke of a single subject, as in "All Frenchmen talk French, Pierre is a Frenchman, therefore Pierre talks French." There was much discussion as to whether such a proposition as "Pierre is a Frenchman" was a universal affirmative or not, it being obvious on all sides that, whether or no, it would have in deduction all the properties of a universal affirmative.

An *enthymeme* is a syllogism in which one premiss is obviously implied, and is the form in which argument is commonly given. For example, "He isn't here; I don't see him," implies that the speaker would affirm himself certain of seeing him if he were there, and is an enthymeme which, with the suppressed premiss restored, makes the following syllogism :—

Fig. 2. A All that is here is seen by me.
Camestres. E He is not seen by me.
Therefore E He is not here.

The *sorites* is a collection of *Barbara* syllogisms, in which the suppressed conclusion of the first is a premiss of the second, that of the second a premiss of the third, and so on; as in A is B, B is C, C is D, D is E, therefore A is E. Here are three syllogisms, namely,

A is B	A is C	A is D
B is C	C is D	D is E
A is C	A is D	A is E

Various attempts were made to classify the manners in which common argument is to be expressed syllogistically. The only difficulty is to reduce the expressions to the pure form of simple assertion or negation. An oblique syllogism was one in which one of the oblique cases enters the premises in such a manner as to vitiate the purity of the form. For instance,

The thoughts of man govern his actions,
John is a man,
Therefore John's thoughts govern his actions.

As it stands, this is not strictly a syllogism, and some less idiomatic expressions must be adopted before it can be turned into one. As,

(Every man) is ⎧ a being whose thoughts
⎩ govern his actions,
John is a man,
Therefore John is a being, &c.

The same thing occurs in a *modal syllogism*, which is one in which some modifying expression gives more or less of force to one or both premises. As

Probably Every Y is X,
Every Z is Y,
Therefore Probably Every Z is X.

If we consider both matter and form, we have here merely a syllogism in which one premiss is only probable. [PROBABILITY.] But, considering form only, the perfect deduction may be made as follows :—

Every Y is ⎧ a thing which is more likely than
⎩ not to be X,
Every Z is Y, therefore every Z is [a thing, &c.]

The *inductive* syllogism is merely one in which one of the premises is proved by induction, or by separate proof of every instance: as when the Ys are known to be A, B, and C, and no more, and Every Y is X is shown by proving separately that A is X, B is X, C is X. There is nothing peculiar to the syllogism here. [INDUCTION.]

The *hypothetical* syllogism (so called) is one in which the truth of one proposition is stated to depend solely on that of another; so that the first can be affirmed as soon as the second is known to be true, or the second can be denied as soon as the first is known to be false. Thus,

If A be B, C is D,
But A is B, therefore C is D.
Or, If A be B, C is D,
But C is not D, therefore A is not B.

Whenever a proof is complete, except in one proposition—when, for example, we have fully made out that C is D, except only in this that the proposition "A is B" is not yet proved, the first member of the hypothetical syllogism lays down the state of the argument. When all that will prove a proposition is true, the proposition itself is true, whence there is only need to affirm the one doubtful premiss, to make the conclusion a logical consequence. Again, when a proposition is false, some part of any logical proof must be deniable: hence there is only need to deny the conclusion in order to make the one doubtful premiss logically deniable.

The *conditional* syllogism is reducible to an hypothetical one. It is when, under certain circumstances, the first member affirms a proposition, as in Wherever A is B, C is D.

The *dilemma* is a double or other compound syllogism, in which two or more contradictory propositions form each a conclusion with other propositions, so that from those other propositions necessarily follows one or other of the conclusions; because of contradictory propositions one must be true. It is not therefore a syllogism, but a collection of them. For example, "He must either have been for, against, or neuter: if for, he was unjust; if neuter, he was mean; if against, he was false; therefore he must have been either unjust, mean, or false." This presumes the existence of a premiss for each conclusion; as for example, that the cause is that of oppression, that he is so circumstanced that nothing but fear or favour could prevent him from taking part with the right, and that he has pledged himself to the wrong.

The rules of syllogism may be briefly condensed as follows :—

1. One at least of the premises must be affirmative, and one at least universal; 2, the middle term must enter universally in one of the premises; and 3, the conclusion must not speak of any term in a wider sense than it was spoken of in the premiss in which it entered. A term universally spoken of is either the subject of a universal affirmative, or the predicate of any negative.

The first rule is derived from observation, but might be demonstrated. The second is seen thus: if the middle term were not universally spoken of in one premise, there might be in reality no middle term, or nothing with which to compare the major and minor term. Thus if we attempt to infer anything from Every X is Y, some Ys are not Xs, we merely see that all the Xs are so many of the Ys, or make up a part of the Ys. Some of the Ys (another portion, it may be) are not Zs, so that the common term does not exist, or may not exist. The third rule is obvious, for no more can be made of any assertion than it contains, and an argument which asserts something about every X from premises which only mention some Xs, must be illogical.

The various species of fallacies must consist either in the introduction of unproved propositions, or an illogical use of those which are proved. We do not feel it necessary to extend this article by entering into the usual classification of them.

SYLVIC ACID, $(C_{40}H_{30}O_4)$ a substance which with pinic acid [PINIC ACID] constitutes the greater portion of colophony, or common rosin. When this substance is digested in cold alcohol of specific gravity 0·833, the pinic acid dissolves, but the sylvic acid remains insoluble in alcohol until it is boiled; on cooling, it separates in crystals of considerable size, the form of which, according to Unverdorben, is a rhombic prism terminated by four facets, but Laurent represents it as an acute rhomboid, the edges of which are usually serrated.

Sylvic acid melts below 212°; is insoluble in water, but dissolves readily in hot alcohol and in ether, and is precipitated by water; it is soluble also in all proportions in the volatile and fixed oils. Concentrated sulphuric acid dissolves and water precipitates it from the acid; by the action of nitric acid it is converted into another resinous acid when it has been precipitated from alcohol by water; ammonia dissolves this acid readily, and the sylvate of ammonia formed, as well as that of potash and of soda, is soluble in water; most sylvates are however insoluble in it, but many of them are dissolved by alcohol and by ether; the sylvate of magnesia especially is taken up by alcohol; the sylvates of silver and lead are colourless and insoluble in water.

SYMBOLS, CHEMICAL. [CHEMICAL FORMULÆ.]

SYMBOLS and NOTATION. The word symbol (from the Greek *sýmbolon*, σύμβολον) means "that which is taken with," and a symbol is a mark which is always attached to some one particular meaning. Notation (*nota*, a known mark) is the method of selecting and assigning meaning to symbols, and the theory of notation (if it yet deserve the name) includes the consideration and choice of symbols, with the formation of rules of selection, so as to take the symbols which are best adapted for the purpose.

This subject might be treated in a very wide manner; for all marks with understood meanings are symbols, from written words to direction-posts. A picture is a symbol, the force of which lies in the resemblance to its object, and many of the earliest symbols must have been pictorial. It is obvious that a general treatment of the subject would hardly be within the power of any one person, and that its extent would be enormous, though it would be desirable to have it discussed in a more general form than has yet been attained, in order that its different parts might receive aid from the rest. Symbols are to the progress of civilisation precisely what mechanism is to that of the arts,—not a moving force, perfectly dead in themselves, but capable of being made the medium by which the power is conveyed to its destination, and adapted to its object. They are the instruments of our first thoughts and the originators of new ones. The process by which the earliest symbols called out a yet higher intelligence than that which produced them, which last was again employed in perfecting the symbols themselves, and so on alternately, exactly resembles what has taken place in the mechanical arts. The earliest and rudest tools were first employed to make better ones; and every improvement in the use force has found one of its best applications in the construction of machinery itself.

We propose in this article to treat particularly of mathematical notation, which, like language, has grown up without much looking to, at the dictates of convenience and with the sanction of the majority. Resemblance, real or fancied, has been the first guide, and analogy has succeeded.

Signs are of two kinds: 1st, those which spring up and are found in existence, but cannot be traced to their origin; 2ndly, those of which we know either the origin, or the epoch of introduction, or both. Those of the first kind pass into the second as inquiry advances. [ALPHABET.] In our present subject we have mostly to deal with the second class.

Mathematical marks or signs differ from those of written language in being almost entirely of the purely abbreviative character, since it is possible that any formula might be expressed in words at length. We say possible, because it is barely so, not meaning thereby to imply that the mathematical sciences could ever have flourished under a system of expressions in words. A well-understood collection of notions, however extensive, becomes simple as a matter of conception by use and habit, and thus becomes a convenient resting-point for the mind and a suitable basis for new combinations of ideas. Now it is the characteristic of the advance of human knowledge that the mind never grapples at once with all that is contained in the notions under use for the time being, but only with some abstraction derived from a previous result, or some particular quality of that result. Hence no symbol which should contain the representative of every idea which occurred in the previous operations would ever be necessary; and more than this, it would even be pernicious from its complexity, as also from its suggesting details which are not required. The generalisation, or rather abstraction, which is the distinctive character of the civilised language as compared with the savage (though the latter is not wholly without it), must be the ruling process of mathematical notation, as it is of the advance of spoken language; and in this point of view the connection of our subject with speech presents more analogies and gives more instruction than its comparison with the written signs of speech. The latter is a bounded subject. When once it is agreed how the different modifications of sound shall be represented, written language follows immediately; nor do the infinite modes of using words require any modification of the method of writing them. In our modern works, for instance, it would be difficult to find many artifices of notation with which to compare the never-ceasing varieties of mathematical signs. In mentioning the marks of punctuation and reference, the italics for emphatic words, and the varieties of print by which notes are distinguished from text, &c., we have almost exhausted the list.

The greatest purposes of notation seem to be answered when the reader or learner can tell what is meant, first, with the utmost certainty, secondly, with sufficient facility; it being always understood that the second must be abandoned when it clashes with the first. Too much abbreviation may create confusion and doubt as to the meaning; too little may give the meaning with certainty, but not with more certainty than might have been more easily attained. Thus the old algebraists, in using A *quadratum* for A multiplied by A, in their transition from words at length to simple notation, used ten symbols where two only are requisite; and those who first adopted the symbol $A\,A$ lost no certainty, and gained materially in simplicity. The successors of these, again, who employed AA, AAA, $AAAA$, &c., to stand for the successive powers of A, were surpassed in the same manner by those who adopted A^2, A^3, A^4, &c. Beyond this it is obvious the notation cannot go in simplicity. The symbol which is to represent "n As multiplied together" must suggest all three components of the preceding phrase—namely, n and A, and multiplied together. In A^n, the n and A are obvious, and the position of the letters is the symbol of multiplication; but, on the other hand, those who teach the beginner to signify by A^2 the square described on the line A, purchase simplicity at the expense of certainty. The same mathematical phrase with them stands for two different things, connected indeed, but of more dangerous consequences from that very connection; for where similarities exist, the reader should not be made to convert them into identities. It is of as much importance to impress the distinction of the things signified as the analogy of their properties.

Certainty, then, and the greatest facility of obtaining it, seem to be the main points of good notation; and this is true with respect to the learner of all that has gone before. Grant that the mathematical sciences are never to advance further, and many alterations might be made, and many new practices adopted, which would give facility in acquiring the past, without any introduction of obscurity. But the future must also be thought of; and no scheme will merit approbation which enlightens one end of the avenue at the expense of the other. Notation influences discovery by the suggestions which it makes: hence it is desirable that its suggestions should be as many, as plain, and as true, as it is possible. Here we are on quite a different ground: reason is the builder and settler, but imagination is the discoverer; and it might turn out that a notation which suggests many and obvious new ideas, though some of them should be fallacious, would be preferable in its consequences to another of less suggesting power, but more honest in its indications. And while we speak of positive suggestion, it must not be forgotten that a notation may be faulty in occupying the part of the symbol which properly belongs to the extension of another notation. The latter is thus deprived of its natural direction of growth, and must find its way elsewhere, to the injury perhaps of some other part of the symbol. In throwing together a few rules, previously to a little description of the present state of mathematical notation, we do not pretend to have exhausted the list of cautions which the subject requires. It is to be remembered that the language of the exact sciences, instead of being, as should be the case, a separate subject, is hardly ever treated at all, and then only in connection with some isolated parts of the system. With the exception of an article by Mr. Babbage, in the 'Edinburgh Encyclopædia,' we do not know of anything written in modern times on notation in general. Much may be collected, having notation for its specific object, from the writings of Arbogast, Babbage, Carnot, Cauchy, J. Herschel, and Peacock, writers who all have considered it necessary, when proposing a new symbol or modification of a symbol, to assign some reason for the proposal. In general, however, it is the practice to adopt or reject notation without giving any justification of the course pursued. If it could be rendered necessary, by the force of opinion, that every author should, in making a new symbol, explain the grounds, firstly, of his departure from established usage,—secondly, of his choice from among the different methods which would most obviously present themselves,—two distinct advantages would result. In the first place, we should in most cases retain that which exists, until something was to be gained by altering it; in the second, research and ingenuity would have a call into action which does not now exist. We hardly need mention a thing so well known to the mathematician as that the progress of his science now depends more than at any previous time upon the protection of established notation, when good, and the introduction of nothing which is of an opposite character. We should rather say the rate of progress; for, however bad may be the immediate consequences of narrow and ignorant views in this respect, they cannot be permanent. The language of the exact sciences is in a continual state of wholesome fermentation, which throws up and rejects all that is incongruous, obstructive, and even useless. Had it been otherwise, it is impossible that the joint labours of three centuries and many countries, of men differing in language, views, studies, and habits, could have produced so compact and consistent a whole, as, with some defects (though no two persons agree precisely what they are), the present structure of mathematical language must be admitted to present.

The following rules and cautions, with respect to notation, are drawn from observation of the present state just alluded to.

1. Distinctions must be such only as are necessary, and they must be sufficient. For instance, in so simple a matter as the use of capitals or small letters, whatever may guide the inquirer to adopt either in one case should lead him to the same in another, unless some useful distinction can be made by the change. Thus a writer who in one instance uses a capital letter to denote a complicated function of small letters (which is a very desirable mode), will in another part of the same question employ a small letter for a similar purpose, thus nullifying an association of ideas which perspicuity would desire to be retained. If such a course were necessary in the first case, it is still more so in the second. It is not often that the second part of this rule is infringed; so small an addition makes a sufficient distinction, that the principal danger which arises is that of the same notative difference occurring in too varied senses in *different* problems.

The tendency to error is rather towards over-distinction than the contrary. It is surprising how little practice enables the beginner in mathematics to remember that so slight a difference as that of a and a' implies two totally different numbers, neither having any necessary connection with the other. The older mathematicians [ACCENT] overdid the use of distinctions by their uniform adoption of different and unconnected letters; and forgot resemblances.

2. The simplicity of notative distinctions must bear some proportion to that of the real differences they are meant to represent. Distinctions of the first and easiest order of simplicity are comparatively few; the complications of ideas of which they are the elements of representation are many, and varied to infinity. There is no better proof of skill than the adaptation of simple forms to simple notions, with a graduated and ascending application of the more complicated of the former to the more complicated of the latter. But some writers remind us in their mathematical language of that awkward mixture of long and short words to which the idiom of our language frequently compels them in their written explanations of the formulæ. For example, if there be two words of more frequent occurrence than any others, they are *numerator** and *denominator;* the parts of a fraction cannot be described under nine syllables. A mathematician will have occasion to write and speak these words ten thousand times, for every occasion on which he will have to use the word *cusp*, of four letters. A comparatively rare idea, used in an isolated subject, can be expressed in one syllable, while the never-ending notions of the parts of a fraction require nine: this he cannot help; but it is in his power to avoid the same sort of inversion in his notation.

3. Pictorial or descriptive notation is preferable to any other, when it can be obtained by simple symbols. Many instances occur in astro-

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* These words might well be shortened into numer and denomer.

nomy, and the use of the initial letters of words may be cited as a class of examples: as in f for force, v for velocity, &c.

4. Legitimate associations which have become permanent must not be destroyed, even to gain an advantage. The reason is, that the loss of facility in reading established works generally more than compensates for the advantage of the proposed notation; besides which, it seldom happens that the desired object absolutely requires an invasion of established forms. For instance, perhaps the most uniform of all the notations of the higher mathematics is the use of the letter d to signify an increment which is either infinitely small, or may be made as nearly so as we please. A few Cambridge writers, some years ago, chose to make a purely arbitrary change, and to signify by dy, dz, &c., not increments, but limiting ratios of increments: and students trained in their works must learn a new language before they can read Euler, Lagrange, Laplace, and a host of others. Thus d_xy has been made to stand for $dy : dx$, and the old association connected with dy has (in the works spoken of) been destroyed. Now if the letter D had been employed instead, the only harm would have been that the student would have had to learn a new language before he communicated with the greatest mathematicians; as it is, many will have to form a new language out of the materials of the old one, which is a much harder task. This injudicious innovation is now extinct.

5. Analogies should not be destroyed, unless false: for true analogy has been frequently the parent of discovery, and always of clearness. Thus the real analogy of $\Sigma\phi x\Delta x$ and $\int\phi x dx$ was lost to the eye by the use of $\int_x \phi x$ to signify the latter; an innovation which preceded the one last-mentioned, and has obtained more approbation in this country, though now almost extinct. The notation used by Fourier to express a definite integral, $\int_a^b \phi x dx$, will certainly prevent the spread of the one just alluded to; though this last itself is chargeable with breach of analogy: for $\int^2 \phi x dx^2$, $\int^3 \phi x dx^3$, &c., ought to represent the successive integrals of $\int \phi x dx$. Fortunately, however, the symbols $(\int dx)^2\phi x$ $(\int dx)^3\phi x$, &c., may represent these successive integrals; and thus the two notations may be combined. For instance, $(\int_0^x dx)^4\phi x$ represents the fourth integral of ϕx, each integration being made from 0 to x.

6. False analogies should never be introduced; and, above all, the incorrect analogies which custom and idiom produce in language should not be perpetuated in notation. It is becoming rather common to make editions of Euclid which are called *symbolical*, and which supply signs in the place of many words. To this, if properly done, there cannot be any objection in point of correctness: nor can we take any serious exception to the use of □ AB to stand for the square on AB, to ‖ for parallel, < for angle, ⊥r for perpendicular, &c. But when we come to AB . BC for the rectangle on AB and BC, AB² for the square on AB, we feel the case to be entirely altered. These are already arithmetical symbols: it is bad enough that the word *square* should have both an arithmetical and a geometrical meaning, and causes plenty of confusion: a good notation, if it cannot help in avoiding this confusion, should at least not make it worse. At the same time, with regard to symbolic geometry, we feel some repugnance to introduce it into the elements, from observing that all the best writers seem to feel with one accord that pure reasoning is best expressed in words at length. If it be desirable that a student should be trained to drop reasoning, except as connecting process with process, and to think of process alone in the intervening time, it is also most requisite that he should have a corrective of certain bad habits which the greatest caution will hardly hinder from springing up while he is thus engaged. Arithmetic and algebra amply answer the first end; and geometry, in the manner of Euclid, is the correcting process. Will symbolic geometry do as well? We will not answer positively, but we must say we much doubt it.

7. Notation may be modified for mere work in a manner which cannot be admitted in the expression of results which are to be reflected upon. The mathematical inquirer must learn to substitute, for his own private and momentary use, abbreviations which could not be tolerated in the final expression of results. Work may sometimes be made much shorter, and the tendency to error materially diminished, by attention to this suggestion.

For example, the complexity of the symbols,

$$\frac{dz}{dx}, \frac{dz}{dy}, \frac{d^2z}{dx^2}, \frac{d^2z}{dx\,dy}, \frac{d^2z}{dy^2},$$

greatly impedes the operations connected with problems in solid geometry: the letters p, q, r, s, t, which are often substituted for them, make us lose sight of the connection which exists between the meanings. But the symbols

$$z_x,\ z_y,\ z_{xx},\ z_{xy},\ z_{yy},$$

are not long nor complicated enough to partake much of the disadvantage of the complete symbols, while they are entirely free from that of the isolated letters.

8. In preparing mathematical writings for the press, some attention should be paid to the saving of room. In formulæ which stand out from the text, this is not of so much consequence; but in the text itself a great deal of space is often unnecessarily lost. For example, it is indispensable in formulæ to write a fraction, such as $\frac{a}{b}$, in the manner in which it here appears; but if this be done in the text, a line is lost; and, generally speaking, $a : b$, or $a \div b$, would do as well in mere explanation. Also, in printing, redundancies which are tolerated in writing, should be avoided, such as $\sqrt{7}$, where $\surd 7$ would do as well.

9. Strange and unusual symbols should be avoided, unless there be necessity for a very unusual number of symbols. The use of *script* letters, such as $\mathscr{A}$, $\mathscr{B}$, &c., or old English letters, as 𝔄, 𝔅, 𝔞, 𝔟, &c., except in very peculiar circumstances, is barbarous. A little attention to the development of the resources of established notation will prevent the necessity of having recourse to such alphabets. Nor is it wise to adopt those distinctions in print which are not easily copied in writing, or which it is then difficult to preserve: such as the use of A and *A*, &c., in different senses; even the distinction of Roman and Italic small letters, a and *a*, &c., should be sparingly introduced.

10. Among the worst of barbarisms is that of introducing symbols which are quite new in mathematical but perfectly understood in common language. Writers have borrowed from the Germans the abbreviation $n\,!$ to signify $1 \,.\, 2 \,.\, 3 \ldots (n-1)n$, which gives their pages the appearance of expressing surprise and admiration that 2, 3, 4, &c., should be found in mathematical results.

The subject of mathematical printing has never been methodically treated, and many details are left to the compositor which should be attended to by the mathematician. Until some mathematician shall turn printer, or some printer mathematician, it is hardly to be hoped that this subject will be properly treated.

The elements of mathematical notation are as follows:—

1. The capitals of the Roman alphabet, and the small letters of the Italic. The small Roman letters and the Italic capitals are rarely used, and should be kept in reserve for rare occasions.

2. The small letters of the Greek alphabet and such capitals as are distinguishable from the corresponding Roman ones, as Δ, Φ, Ψ.

3. The Arabic numerals, and occasionally the Roman ones.

Of all these there should be three different sizes in a good mathematical press, and the different sorts should bear a much better proportion to one another than is usual. The Greek letters seldom set properly with the Roman ones, and few indeed are the instances in which such symbols as

$$a^{m^n} \qquad \epsilon^{(1+t)^2}$$

are, as they ought to be, good copies of the manner in which they are written. The handwriting of a bad writer is frequently more intelligible to the mathematical eye than the product of the press. Among the faults to which the compositor is naturally subject, and which frequently remain uncorrected by the author, is that of placing blanks or spaces in the manner in which he would do in ordinary matter, by which he is allowed to separate symbols which are in such close connection that absolute junction would not be undesirable. For instance, $\cos\ \theta$ for $\cos\theta$, $(a\ b+c\ d)$ for $(ab+cd)$. As a general rule, the manuscript should be imitated.

4. Accents, superfixed and suffixed, as in a'', $a_{\prime\prime}$. These are generally continued, when they become too numerous, by Roman numerals, as in $a_{\prime}$, $a_{\prime\prime}$, $a_{\prime\prime\prime}$, a_{iv}, a_{v}, a_{vi}, &c.

5. The signs $+ - \times \div : \surd$, and the line which separates the numerator from the denominator. Of these there are generally not sizes enough, particularly as to the sign $-$. It frequently happens that such an expression as $(x-1)\ (x-2)\ (x-3)$ &c. overruns a line very inconveniently, when the use of a shorter negative sign, as in $(x{-}1)$ $(x{-}2)$ $x{-}3)$ would avoid such a circumstance altogether. Between the division line of a fraction and the numerator and denominator unsightly spaces very often occur, as in

$$\frac{a+b}{\;c+d\;} \text{ instead of } \frac{a+b}{c+d}.$$

6. The integral sign $\int$. with its limits expressed, as in $\int_a^b$: the symbols of nothing and infinity, 0 and ∞.

7. Brackets, parentheses, &c. [ ], ( ), { }, &c. These are often not properly accommodated to the size of the intervening expressions, particularly in thickness.

8. The signs of equality, &c., $=$, $<$, $>$.

9. Occasionally, but rarely, a bar or a dot is used over a letter, as $\bar{a}$ or $\dot{a}$. In some works, accents and letters are placed on the left of a symbol, as in ${}'a$, ${}^2a$, ${}_2a$. This however should be avoided, as it is difficult to tell to which letter the symbol belongs; and there are ample means of expression in what has been already described.

There are no general rules laid down for the use of notation: a few hints however may be collected from the practice of the best writers of recent times.

1. When a letter is to be often used, it should be, if possible, a

small letter, not a capital. The latter species is generally used for functions of small letters.

2. The letters d, Δ, δ, and D, are appropriated for operations of the differential calculus, and should hardly ever be used in any other sense.

3. When co-ordinates are used, the letters x, y, z, must be reserved to signify them; x, y, z, and ξ, η, ζ may be used if different species be required, and if x', y', z', &c., or $x_{,}, y_{,}, z_{,}$ &c., should not be judged convenient.

4. When functional symbols are wanted, the letters ϕ, ψ, χ, F, f, Φ, Ψ, should be first reserved for them; afterwards π, ϖ, τ, sometimes π, ξ, μ, ν.

5. The letter π is, by universal consent, appropriated to 3·14159 . . . , and ϵ (by the French e) to 2·71828 . . . . ; Γ to the functional symbol for 1 .2.3. n.

6. When many operations of differentiation occur, superfixed accents should be avoided in any other sense than that of differentiation.

7. When exponents are wanted to aid in signifying operations, the powers should be carefully distinguished. Thus, in a process in which $\sin^{-1}x$ is very much used for the angle whose sine is x, the square cube, &c., of $\sin x$ should not be $\sin^2 x$, $\sin^3 x$, &c., but $(\sin x)^2$, $(\sin x)^3$, &c. Some writers would have the latter notation employed in all cases; but this is, we think, asking a little too much.

8. Greek letters are generally used for angles, and Italic letters for lines, in geometry. To this rule it is desirable to adhere as far as possible, but it cannot be made universal.

9. Suffixed numerals are generally the particular values of some function. Thus a_v means a function of v, of which the values for $v=0$, $v=1$, &c. are a_0, a_1, &c.

10. As to the radical sign, $\sqrt{a}$, $\sqrt[3]{a}$, &c., do not generally mean any one of the square roots, cube roots, &c., of a, but the simple arithmetical root. The indeterminate root is usually denoted by the exponent. Thus $a \pm \sqrt{b}$ may be necessary, but $a \pm b^{\frac{1}{2}}$ has a superfluity.

11. The same letters should be used, so far as possible, in the same sense throughout any one work; and some preceding good writer should be followed. As a general rule, those only are entitled to invent new symbols who cannot express the results of their own investigations without them.

The writer who is most universally acknowledged to be a good guide in the matter of notation is Lagrange. This subject is of great importance; but fortunately it is pretty certain that no really bad symbol, or system of symbols, can permanently prevail. Mathematical language, as already observed, is, and always has been, in a state of gentle fermentation, which throws up and rejects all that cannot assimilate with the rest. A received system may check, but cannot ultimately hinder, discovery: the latter, when it comes, points out from what symbolic error it was so long in arriving, and suggests the proper remedy.

For the progress of mathematical language, see MATHEMATICS, RECENT TERMINOLOGY IN; and TRANSCENDENTAL: see also SYMMETRY.

SYMMETRY, SYMMETRICAL (Mathematics). These terms are now applied to order and regularity of any kind, but this is not their mathematical meaning. Euclid first used the word "summetros" (σύμμετρος) to signify *commensurable*, and this well-known Latin word is in fact merely the literal translation of the Greek: two magnitudes then were symmetrical which admitted of a common measure. In later times, and those comparatively recent, the word was adopted both in geometry and algebra in different senses.

Since symmetrical applies in its etymology to two magnitudes which can be measured together (by the same magnitude), the term would, as to space-magnitudes, naturally apply to those which may be made to coincide. But the term *equal* had occupied this ground; and when, in Euclid, the word equal, which was originally defined in the manner just expressed, had degenerated into signifying equality of area only, the term SIMILAR entered to express sameness of form, so that figures having perfect capability of coincidence, or the same both in size and form, were called equal and similar. The word symmetrical was therefore not wanted, and was finally introduced to signify that obvious relation of equal and similar figures which refers to their position merely, and consists in their corresponding portions being similarly placed on *different sides* of the same straight line; so that coincidence cannot be procured without turning one figure round that straight line. Suppose, for instance, the front of a building to be *symmetrical*: draw a vertical line through the middle of the elevation, and the two lateral portions are equal and similar, as Euclid uses those words. But they are more than equal and similar; they are symmetrical: the right-hand side stands in the right-hand portion of space, with respect to the dividing line, and in exactly the same manner as the left-hand side stands in the left-hand portion of space. If the architect were to preserve equality and similarity, without symmetry, he would make two left sides, or two right sides, to his building, but not one right and one left. In the letter W there is a want of symmetry, but not in O: to make W symmetrical, both the inner lines should be thin, and both the outer ones thick.

Euclid assumes the power of turning a plane round, so as to apply the faces of two figures to one another, in such manner that, after the application, the spectator must be supposed to see through the paper or other imaginary substance of which his plane is the surface. He has then no occasion to consider symmetry; that is, figures being equal and similar, no cases can arise in which it makes any difference of demonstration whether they be symmetrical or not. When he comes to solid figures, he assumes a postulate in the garb of a definition, which dispenses him from the consideration of symmetry; namely, that solid figures consisting of the same number of equal planes, similarly placed, are equal. He seems to imagine that such solids must evidently be capable of being made to occupy the same space, which, though true as to quantity of space, is not true as to its disposition. Two solids may be equal in every respect, and yet it may be impossible (and precisely on account of their symmetry) to make one occupy the space previously occupied by the other. The two hands furnish an instance: they give the idea of equality (of size), similarity (of form), and symmetry (of disposition). Yet they cannot be made to occupy the same space, so as, for instance, to fit exactly the same glove; and a sculptor who should cast both hands from the same mould, would be detected immediately as having given his figure two right hands or two left hands. Again, suppose two solids, irregular pyramids for instance, composed of planes similar and equal, each of one to one of the other. Let coincidence be attempted geometrically: the two bases must of course be made to coincide. If, then, the two vertices fall on the same side of the common base, the figures will coincide altogether; but if the two vertices fall on opposite sides of the bases, absolute coincidence is impossible. Legendre proposed to call such solids by the name of *symmetrical*, in doing which he introduced the term of common life in an appropriate manner.

In algebra, a function is said to be symmetrical with respect to any two letters when it would undergo no change if these letters were interchanged, or if each were made to take the place of the other. Thus,

$$x^3 + a^2x + ab + b^2x$$

is symmetrical with respect to a and b; interchange would give

$$x^2 + b^2x + ba + a^2x,$$

the same as before. But this expression is not symmetrical with respect to a and x, for interchange would here give

$$a^2 + x^2a + xb + b^2a.$$

An expression is symmetrical with respect to any number of letters when any two of them whatsoever may be interchanged without alteration of the function. Thus $a^2b + ab^2 + a^2c + ac^2 + b^2c + bc^2$ is symmetrical with respect to a, b, and c. It is not sufficient that certain contemporaneous changes should be practicable without producing alteration: *any two* must be interchangeable, the rest remaining. Thus $a^2b + b^2c + c^2a$ is unaltered if a become b, b become c, and c become a, at the same time, but it is not symmetrical; for if a and b only be interchanged, it becomes $b^2a + a^2c + c^2b$, or is altered.

Attention to *symmetry* is of the utmost consequence in mathematical notation. Here the word means that quantities which in any manner have a common relation should have something common in the symbols of notation; and analogy is perhaps a better word than symmetry. Suppose, for instance, we had taken, for the equation of a SURFACE OF THE SECOND DEGREE, $ax^2 + by^2 + cz^2 + dxy + exz + fyz + gx + hy + kz + l = 0$. Our formulæ would have been confused masses of letters, no set of which would have presented any similarity, or have easily remained in the memory. But in the article cited there is no set of formulæ of which more than one need be remembered; the others must be suggested by it.

SYMMETRY, CENTRE OF. [CENTRE, col. 734.]

SYMPATHETIC INK. [COBALT.]

SYMPHONY (σύν, *with*, and φωνή, *sound*), a term very differently understood at different periods of musical history. Some writers, according to Zarlino (Parte 3za, cap. lxxix.), have considered it as an instrument of the lyre kind. Others have thought it a sort of drum. If an instrument, that it was used as an accompaniment—most probably to the voice—the word in its original signification leads us naturally to conjecture.

With the moderns, Symphony, or *Sinfonia*, signifies a musical composition for a full band of instruments, and, up to the latter part of the last century, the word was synonymous with overture; symphonies, and among these several of Haydn's early ones, having been called overtures. Even at the present day the overture in the composer's score of an Italian opera is usually termed *Sinfonia*. The modern symphony generally consists of four movements: a brilliant allegro, which is commonly preceded by a slow introduction; an expressive adagio or andante; a minuet with its trio; and a finale. Instead of the minuet, what is called a *Scherzo*, a short, animated, sportive movement, is sometimes substituted. But composers are not restricted by any rule regarding the number of movements. Mozart's second symphony in D has but three, besides the slow introduction; while Beethoven's Pastoral and Choral symphonies may be said to comprise six or more.

Symphony is a term also applied to the instrumental introductions, terminations, &c., of vocal compositions; and these are sometimes called ritornels, from the French *ritournelle*, or the Italian *ritornello*.

SYMPIESOMETER. [BAROMETER.]

SYMPTOM (συμπτωμα, an incident, or coincidence) is any change in the appearance or functions of the body differen from those which occur in health, and perceptible to the senses either of the patient or his physician. Symptoms must not be confounded with signs of disease. The observation of facts by means of our senses renders us acquainted with symptoms, but it is by medical reasoning thereupon that we deduce signs. A patient often knows his own symptoms, but is nevertheless ignorant of the disease under which he labours.

The signs of disease are inferences drawn by the mind from the observation of symptoms. The most striking symptoms often furnish only accessory signs, while the most obscure are the signs characteristic of the disease. Violent pain in the head not unfrequently attends inflammation of the lungs, but is a symptom of very small importance, while slight pain in the side, or a streak of blood in the expectoration, furnishes a very valuable sign, and helps to disclose the nature of the affection.

Symptoms are best divided into the *essential*, which are peculiar to certain diseases, the *accidental*, produced by some circumstance of unusual occurrence, and the *common*, which are met with alike in various complaints.

That part of medicine which treats of symptoms is called Symptomatology: Semeiology is the name applied to the investigation of the signs of disease, and of their comparative value.

SYNAGOGUE (*Συναγωγή*), a word which primarily signifies any assembly or congregation, but came to be applied, among the Jews, to places where any assemblies, especially those for the worship of God, met, or were convened. In the later Hebrew, such places were called בֵּית כְּנֶסֶת, "house of assembly." There is no trace of synagogues among the Israelites prior to the Babylonish captivity, nor, in express terms, until a long time after. It is collected, however, that the origin of such establishments may be referred to that period. Being then debarred from their customary religious observances, they were accustomed to assemble on the Sabbath-day, to hear portions of the law read and expounded; and those who ultimately returned from exile kept up this custom in Palestine. (Nehem. viii. 18.) These assemblies or meetings became in due time fixed to certain places, and a regular order was observed in them. They existed considerably earlier among the Jews settled in foreign parts than in their own country, where we do not find them until the time of the Asmonæan princes; but after their introduction they increased rapidly. The synagogues appear to have been originally erected outside the towns, in the fields, usually near waters, for the benefit of ablution; but they were soon introduced into the towns, and were usually on the most elevated spots. In large towns there were several, and the Jewish writers affirm that there were 480 in Jerusalem. The assemblages were at first confined to the Sabbath-days and festivals, but were latterly extended to the second and fifth days of the week (Mondays and Thursdays). The services consisted chiefly in prayer, and in the reading and exposition of the sacred books. At first the readings were confined to the law, but were at length made to comprehend portions of the prophets, psalms, and other books. The whole concluded with a prayer and benediction, to which the congregation responded "Amen."

It seems to have been the custom for a synagogue not to be opened in any place where ten men could not be found of sufficient leisure to attend to its affairs. Where no separate building existed, a room in some private house was the place of meeting. There are no ancient indications that the synagogues had any peculiar form; but each of them had a kind of altar or table, at which the volume of the law was read; and at the east end was an ark or chest in which that volume was kept. The seats were so disposed that the face of the people was turned towards this sacred repository and towards the elders, who alone sat with their backs to the ark, and their faces to the people. The synagogues were used not only for worship, but for holding local courts of justice, which had cognisance of petty offences requiring no higher punishment than stripes, which were inflicted on the spot. (Matt. x. 17; Luke, xii. 11; Acts, xxii. 19.) The affairs of the synagogue were under the direction of several officers: the chief of them was the archisynagogus (*ἀρχισυναγωγός*), or "ruler of the synagogue," who regulated its affairs, and without whose leave no one could read or preach. (Mark, v. 22; Luke, xiii. 14.) Next to him was the officer called שְׁלִיחַ צִבּוּר "Sheliach tsibbor," or "angel (messenger) of the church," who prayed in behalf of the congregation. The חַזָּן "Chazan," who is the reader in modern synagogues, appears to have been the "minister" (Luke, iv. 20) who had charge of the sacred books. As it appears from Acts, xiii. 15, that there were several archisynagogi, it is probable that they answered to the committee of elders, by whom the synagogues are at the present time managed.

With some necessary modifications, the ancient usages are still maintained in the modern synagogues. The highest ground that can be conveniently appropriated is still chosen for the site of a synagogue. In this part of the world it extends east and west, with the entrance, or principal entrance, in the west, that as the people enter, and as they sit, their faces may be turned towards the land of Canaan. The altar or desk is on a raised platform surrounded by a wooden rail, and large enough to contain several persons: the women do not mingle with the men, but have a separate part or gallery (if there be one), where a wooden lattice screens them from observation. The men keep their heads covered in the synagogues.

The first synagogue in England of which we have historical knowledge is that which, in the reign of William Rufus, existed at Oxford, where the Jews were then numerous; but it is likely that they had one then or before in London also, as the fact that their only burial-place in England was on the spot now called Jewin Street, indicates that this was their principal seat. In the reign of Henry III. they lost a synagogue, which they had erected in the Old Jewry, on the complaint of the Friars Penitent in the neighbourhood, that they could not consecrate the elements in quiet on account of their "howlings. So late as the reign of George II. the only synagogues allowed in England were the two in London, one for the Portuguese Jews in Bevis Marks, and the other for the German Jews, in Duke's Place There is now no restriction; they have several synagogues in London and at least one in most of the principal towns, and the total number in England was fifty-three in 1860.

SYNAPTASE. [Ferment.]

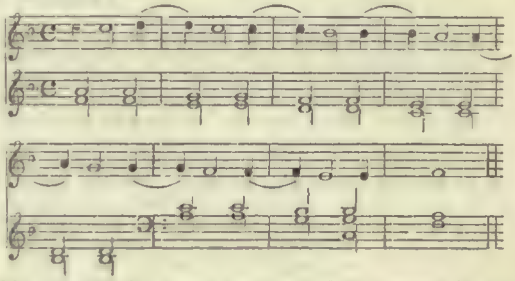
SYNCELLUS (*σύγκελλος*), a Greek word, equivalent to *concellaneus* in Latin, and meaning a person who inhabits the same chamber (*cella*) with another, was used by the Christians of the early and middle ages as the name of an ecclesiastical dignity. The Syncellus was constantly with the patriarch, metropolitan, or bishop, as an inspector of his life and manners. The successors to the patriarchs and metropolitans were very often chosen from the Syncelli. Their rank was very high, and at one time they even claimed precedence over the metropolitans. Their number was considerable, till by a constitution of Heraclius the greatest number allowed in one church was two.

The chief of the Syncelli was called Protosyncellus (*πρωτοσύγκελλος*), and the president of their assemblies was called *πρωτοπρόεδρος τῶν πρωτοσυγκέλλων*.

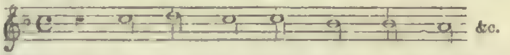
The suffragan bishops [Bishop] were also called Syncelli.

(Du Cange, *Glossar. Med. et Inf. Latin.*, s. v. 'Syncellus.')

SYNCOPATION, in Music, is when the first half of a note begins on the unaccented or weak part of a bar, and the other half is continued and terminates on the accented or strong part. [Accent, *in Music.*] Example:—



In this example the upper part, or melody, consists in fact of a succession of syncopating minims; but the bar dividing the alternate ones, they can only be written as two crotchets bound together: though formerly the bar was, in most cases, made to cut the note in two. Example:—



Syncopated notes are, by some writers, termed *driving notes.*

SYNCOPE (*συγκοπή*, literally a cutting in pieces, a sudden failure of power or strength), fainting. A sudden impairment or complete loss of sensation and voluntary motion, with great diminution or almost total abolition of the heart's action and of the function of respiration.

Fainting sometimes occurs quite suddenly, but is usually ushered in by certain premonitory symptoms. These are a sense of languor and uneasiness, confusion of the mind, oppression at the chest, dimness of sight, ringing in the ears, partial cold sweats, paleness of the face, and coldness of the extremities. These continue for some time, and then either pass away, or are followed by swooning, a state of complete faintness, during which the pulse is altogether imperceptible at the wrist, and respiration nearly ceases. When a fainting fit comes on suddenly and without any warning, it is usually more profound than when it has been preceded by the symptoms just enumerated. Recovery from fainting is frequently attended with palpitation of the heart, and sensations more distressing than those which ushered in the attack. The duration of a fainting fit seldom exceeds a few minutes or even seconds, but instances are on record of persons continuing in a swoon for many hours.

The immediate cause of fainting is, in all instances, some interruption to the due transmission of blood to the brain. Various circumstances however, both moral and physical, interfere with the circulation, either through the medium of the nervous system, or by acting directly on the heart itself. Persons swoon from any violent and sudden moral emotion, as terror, grief, disappointment, or even excessive joy. The sight of blood or of any object which excites disgust occasions some persons to faint, as do various impressions on the senses, whether painful or otherwise. Very susceptible individuals have been known to faint on perceiving the odour of certain flowers, and unpleasant smells still more frequently cause faintness. The abstraction of a large quantity of blood probably has a more immediate action on the heart; and to the disturbance of the circulation must be attributed those fainting fits which sometimes occur in the course of diseases of the heart. The sudden transition from a horizontal to a sitting posture when persons are very weak, or have lost a large quantity of blood, probably acts in both ways at once; and fainting sometimes takes place from other causes, such as heated rooms, &c., of which we cannot well explain the action.

Fainting may be confounded with apoplexy or asphyxia; and if it continues for an unusually long time, the person may be supposed to be dead. A little attention however will prevent our mistaking an apoplectic person, who breathes loudly and with a snoring noise, for a person in a swoon, whose respiration is gentle, and almost imperceptible, and whose pulse either cannot be felt at all, or is at any rate extremely weak. Asphyxia is a state of suspended animation, brought on by some cause interfering directly with respiration; it is marked by tumor and lividity of the face, while the face of a person in a fainting fit is pale and sunken. The continuance of respiration and of the heart's action, though very feeble, the temperature of the body, and the absence of all stiffness of the limbs, would sufficiently distinguish syncope from death; but it must be very unusual for fainting to continue for a few minutes without there appearing some evident signs of life. [ASPHYXIA.]

In the treatment of a person who has fainted, the first point is to place him in the recumbent posture; and in the case of fainting after blood-letting, nothing more is in general required. Exposure to the cool air, sprinkling cold water on the face, and friction of the limbs may be employed if the fit continues; and a small quantity of ether or sal-volatile may be given as soon as the person can swallow. The horizontal posture should be preserved until recovery is complete.

SYNDIC comes from the Greek "syndicos" (σύνδικος). The Greek word Syndicos originally signified one who aided another in a matter before a court of justice, and hence it came to signify generally an advocate, one who maintained another's cause before a court of justice. Syndicos also signified at Athens one who was appointed by the state to attend to its interests in any matter in dispute between Athens and another state: thus Æschines was elected their Syndicos by the Athenians in a matter relating to the temple at Delos. (Demosthen. Περὶ Στεφάνου, c. 42.) There were also functionaries at Athens called Syndici, who were appointed, after the establishment of the tyranny of the Thirty, to decide on cases of confiscated property. The word Syndicus passed into the Latin language. It often occurs in the 'Digest' in the sense of an attorney or agent for a university or corporate body: in this sense it is used as synonymous with Actor by Gaius. ('Dig.' 3, tit. 4, s. 1.) In the middle ages also the word Syndicus was in common use, and was frequently given to the agent or factor appointed by corporate bodies to manage their common affairs, and especially to represent them in courts of law. Crevier, in various places, designates the syndic of the university, or of the faculty of arts, by the equivalent names of procureur, agent, greffier (iii. 230; iv. 309; v. 459). In the same sense most of the other corporate bodies in Paris and other French towns used to have their syndics; and the syndic was also the usual name for the solicitor to the community, or town-clerk, in the towns of Languedoc and Provence. The clergy, in like manner, had their Syndics Généraux, Syndics Diocésains, and Syndics Provinciaux; and Syndics, or agents resident at Paris, were also appointed by most of the religious orders. The functions of the different syndics however varied considerably; some were mere agents or solicitors, others were representatives of their corporations in a higher sense, sometimes acting as their presidents, and deciding causes, instead of merely conducting them. The four chief magistrates of the city of Geneva used to be called Syndics. Among the Burdegalenses (or people of the district of which Bordeaux is the capital), the office of Syndic, supposed to have meant originally the defender of a military post, became in course of time an hereditary title of nobility; of which several instances occur in Froissart, and other chroniclers of the 14th century. In more recent times, when Louis XIV., in 1701, directed the establishment of chambers of commerce in the principal towns of France, the merchants and other persons composing them were appointed to be called Syndics du Commerce, or Syndics de la Chambre de Commerce. For the significations of the various old words derived from or connected with Syndicus, the reader is referred to Ducange, 'Gloss. M. et I. L.,' vi. 928-931; and 'Supplem.,' iii. 932. We shall merely mention that the French have the verb "syndiquer," for to judge or censure, as we formerly said "to syndicate" in the same sense.

SYNOCHUS and SYNOCHA, forms of fever recognised by most of the older and many recent writers on the practice of medicine. Sauvages defined Synochus to be a fever which lasted more than a fortnight without materially weakening the pulse; whilst Cullen used this term to express a fever which combined the two forms of inflammatory and putrid fever, that is, a fever which at its commencement was inflammatory and at its close putrid. The inflammatory form of fever which was characterised by running its course rapidly, and marked by high excitement of the heart and arteries, was called Synocha by Cullen. A putrid and low form of fever was called Typhus. The latter term is now, however, applied to all continued contagious fevers, and the former terms are not often used at all. [FEVER, CONTINUED.]

SYNOD, a Greek word, Σύνοδος (literally, "a coming together"), adopted by the Saxons, sometimes used for an assembly of any kind, but much more commonly for an assembly gathered for ecclesiastical purposes, and more particularly for an assembly of bishops or presbyters deputed by various churches or branches of the universal church to meet at an appointed place, there to deliberate on points of doctrine or other matters relating to the regulation and welfare of the church. These synods are also called councils. Of these the highest are called œcumenical, by which is meant representative of all the different branches of the church established throughout the habitable world (οἰκουμένη). [ŒCUMENICAL COUNCILS.]

Very few synods or councils have been held in the Protestant churches. By far the most remarkable is that of Dordrecht or Dort, which was assembled in the reign of our king James I. Its professed object was to compose the differences existing between the Calvinian and Arminian parties in the Protestant church. The former prevailed.

The doctrine of the Church of England respecting councils may be seen in the Twenty-first Article.

Lists, very full and perhaps complete, of the several councils which have been held, may be found in many treatises on chronology, particularly the 'Tablettes Chronologiques,' of M. Dufresnoy; and in 'L'Art de Vérifier les Dates.'

SYNODIC, SYNODIC REVOLUTION (σύνοδος, conjunction of paths). The synodic revolution of two bodies which move round a common centre is that portion of one or more actual revolutions in which they go through all their possible relative positions. The simplest instance which can be given is that of the two hands of a watch: the absolute revolution of the minute hand is made in one hour, that of the hour hand in twelve hours; but the synodic revolution of the two hands is the interval which elapses between any time at which they are together, and the next time at which the same thing takes place.

Every phenomenon which depends upon the relative position of two revolving bodies cannot complete all its phases in less than a synodic revolution. Thus, in the case of the sun and moon, the total disappearance of the latter which takes place when they are nearest in the heavens, cannot take place again until they are again at their nearest, that is, until the moon has not only completed the circuit of the heavens, but has further progressed until she overtakes the sun. The actual revolution of the moon is not an object of interest, except to those who watch her progress among the fixed stars: the phases which are visible to all the world depend solely on her motion relatively to that of the sun. Those who would make a common watch tell time in a manner resembling the indications of luni-solar phenomena must rub out the marks of minutes and hours from the dial-plate, and choose for an interval of measurement that which elapses between successive conjunctions of the minute and hour hands.

If the two revolutions be made in the same direction, and if T and t be their respective times, T being the greater, the time of the synodic revolution is

$$\frac{Tt}{T-t}.$$

For, if x be the time of a synodic revolution, the portion of an actual revolution which the quicker has gained upon the slower is

$$\frac{x}{t}-\frac{x}{t};$$

but by hypothesis this is a whole revolution, since the synodic period is nothing but the time in which the quicker gains a whole revolution upon the slower. Equate the last formula to unity, and the resulting value of x is the first formula. But if the two revolutions be made in opposite directions, the synodic revolution is made in the time

$$\frac{Tt}{T+T}.$$

Thus in the case of the hands of a watch, $T=12^h$, $t=1^h$; and $\frac{12}{11}$ of an hour, or $1^h\ 5^m\ \frac{5}{11}$, is the interval of two conjunctions of the two hands.

To find roughly the synodic period of the sun and moon, let us take the sun's actual revolution at 365¼ days, and moon's at 27¼ days. We have then

$$\frac{365\frac{1}{4}\times 27\frac{1}{4}}{365\frac{1}{4}-27\frac{1}{4}}=29\tfrac{1}{2}\text{ days nearly.}$$

SYNONYME. The word synonyme is applied to different words, which mean, or are supposed to mean, the same thing: as valour, courage; virtue, goodness; vice, wickedness. Though words are often considered to be synonymous, it is probable that very few words in the same language really are synonymous. If we compare two languages, we may find synonymes; thus the words for man, horse, dog, &c., taken in any number of languages, may be considered synonymous. Words belonging to the same language may also be synonymous, where the language has received additions from various other languages, among which additions there may be terms which are synonymous (in the modern sense) with native terms of the language into which they are introduced. Thus in English there may be Saxon terms which are, or rather once were, synonymous with other terms which have been introduced into the English immediately from the Latin, or through the medium of the Italian and the French. It is said "once were," because though such words may have been synonymous originally, and introduced by writers for the sake of variety or harmony, or to avoid repetition of the same word, it rarely happens that such words continue to have their original meaning.

SYNTAX. [Language; Organon.]

SYNTHESIS. [Analysis.]

SYNTHESIS, CHEMICAL. The process of forming a chemical compound from its constituents; thus the production of phosphoric acid by the combustion of oxygen in air is a synthetical operation. The synthesis of inorganic substances is generally easily accomplished, but that of organic bodies is much more difficult. [Organic Compounds, *Artificial production of.*]

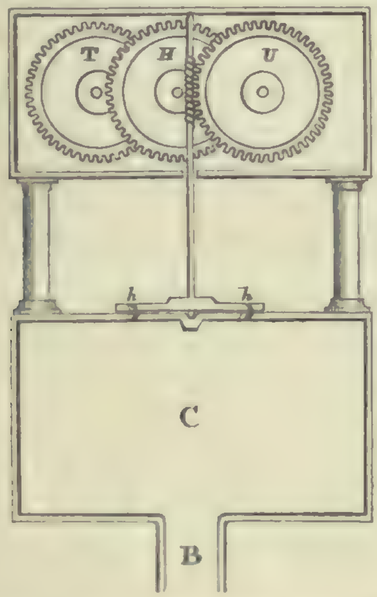
SYNTONIN. A name given by Mulder to the fibrin of the muscles.

SYPHON. [Siphon.]

SYPHON GAUGE. [Siphon Gauge.]

SYPHON, REVERSED. [Water Works.]

SYREN, an instrument invented by M. Cagniard de la Tour for determining the number of vibrations per second of any given note.



The fanciful name of the instrument was given from the fact that it is capable of exciting vibrations in water or any other fluid. It consists of a cylindrical chamber of brass C, about 3 inches in diameter, and 1½ inch high, connected with which is a tube B, which fits into the tube of a double pair of bellows. The upper surface of C contains a circle of holes, inclined somewhat obliquely, and coinciding with this circle is another circle of holes, inclined at an angle with the first, and contained in a disc of metal *h*, free to move on a vertical axis. This axis has near its upper extremity a perpetual screw which gives motion to a wheel U, of 100 teeth, and this acts on a hundreds wheel, marked H, and this again on a thousands wheel, marked T. Now suppose each circle of holes to contain 25. On sending a blast of air through B, it will, in escaping through the holes in C, cause the disc *h* to rotate with a speed depending on the force of the blast, and during each turn of the disc the currents will be cut off and re-opened 25 times, producing in fact, 25 waves of sound. One hole in each disc would produce, with a given velocity, the same note as 25, but the larger number produces a louder tone. By regulating the force of the blast, the disc may be made to vary in speed, so as to produce notes from the gravest to the most acute. By making the syren give the note, the velocity of whose vibrations we wish to determine (that of a tuning fork for example), the total number of rotations of the disc, as recorded by the dials attached to the wheels U, H, T, divided by the number of seconds during which the observation is being made, will give the number of vibrations per second for the note in question. By a simple adjustment, the endless screw can be put in and out of gear with the teeth of the wheels in a moment, so that the registration need not begin until the instrument is sounding the note fully and freely. A seconds pendulum should also be at hand, beating audibly, so that the observer may begin to count the moment the screw is put in gear. Some practice is required to make the instrument sustain the note for 8 or 10 seconds. Graduated dial-plates and moving hands, as in a gas-meter, are connected with the wheels U, H, T, so that the number of vibrations can be read off by simple inspection.

SYRIAC LANGUAGE. [Aramæan Language; Language.]

SYRIAC VERSIONS of the Bible. Of these several exist, two of which are of considerable importance. 1. "The Peshito (*literal*) Version," also called "The Old Syriac Version," is one of the most ancient and valuable translations of the Bible. The date of its execution is unknown; but it is certainly of a high antiquity. It is referred to by Ephrem the Syrian, in the middle of the 4th century, as generally known and used, and therefore it must have been in existence a considerable time before. Modern critics have referred its date variously to the 1st, 2nd, and 3rd centuries, the majority to the 1st. The opinion now generally adopted is that of Michaelis, who ascribes the translation of both Testaments to the most flourishing period of the Syrian Churches, namely, the end of the 1st and the beginning of the 2nd century.

The version of the Old Testament was certainly made from the Hebrew, which it closely follows; but there are indications of the translator having made use of the Septuagint and of the Chaldee paraphrase. The great antiquity of this version, much higher than that of any existing Hebrew manuscript of the Old Testament, makes it a most valuable source of biblical criticism. It is on the whole a very good translation, but not equal throughout. A different method of interpretation is followed in different books, for instance in the Pentateuch and the Chronicles. From this circumstance Jahn infers that it was the work of different persons. Several peculiarities tend to prove that the translators were Christians, and probably converted Hebrews.

The version of the New Testament contains the four Gospels, the Acts of the Apostles, the Epistles of Paul (including that to the Hebrews), the First Epistle of John, the First Epistle of Peter, and the Epistle of James. It is undoubtedly one of the best versions of the New Testament in any language, and is used as their standard by the churches of Syria and the East.

The version of the Old Testament was first printed in the Paris Polyglott, but from an imperfect manuscript; the passages which were wanting were indifferently translated by Gabriel Sionita from the Vulgate. This text, revised by the help of four manuscripts, was reprinted in Walton's Polyglott, but was on the whole carelessly done. The best version is that of the Rev. C. Buchanan and Professor Lee, published by the British and Foreign Bible Society in 1816, which has been translated by the Rev. James Murdock, and was published in New York in 1851. The version of the New Testament was first brought into Europe by Moses of Mardin, who was sent by Ignatius, the patriarch of Antioch, on a mission to Pope Julius III. in 1552. It was first printed at Vienna in 1555, at the expense of the emperor Ferdinand I.

There is a later and very inferior translation of the books of the New Testament which are wanting in the Peshito, namely, the second Epistle of Peter, the second and third of John, the Epistle of Jude, and the Apocalypse, made from the original Greek, probably in the 6th century.

2. The Philoxenian, or Syro-Philoxenian Version of the New Testament, is so called from Philoxenus, bishop of Hierapolis, in the province of Aleppo (488-518), under whose auspices it was translated by Polycarp. It was revised by Thomas of Heraclea in 616. It is translated from the Greek text, but is very inferior to the Peshito.

In 1842 an imperfect copy of the four Gospels was brought by Archdeacon Tattam from the monastery of St. Mary Deipara in Syria, and is now in the library of the British Museum. It has been carefully edited, and translated by Dr. William Cureton, who considers its date to be of the 5th century. It differs from the Peshito, as well as from the Septuagint and the Greek in many passages, which are pointed out by Mr. Cureton in the printed edition published in 1858.

There are other Syriac Versions, not of sufficient importance to require a separate notice.

A list of the editions of the Syriac Versions is given in the 'Bibliographical Appendix' to the second volume of Horne's 'Introduction.'

SYRINGE (from Σύριγξ, a pipe), a portable hydraulic instrument of the pump kind, commonly employed for the forcible ejection of fluids. In its simplest form it consists of a cylindrical tube, with a perforated nozzle at one end, and a piston, to the rod of which a handle is attached. The tube being held in the left hand, with its nozzle immersed in water, the piston is drawn to the upper end of the tube by the right hand. The pressure of the atmosphere upon the surface of the water causes it to follow the piston, so that the syringe becomes filled with water. The instrument is then removed from the vessel of water, and, by pushing the piston back towards the nozzle, its contents may be ejected with a force proportionate to the power applied to the piston.

The use of syringes for extinguishing fires is alluded to under Fire-Engine. They were usually made of brass, and held from two to four quarts each. Those of the former capacity were about two feet and a half long, and one inch and a half in diameter, that of the nozzle being half an inch. They were furnished with handles on each side, and every syringe required three men to work it. The large syringes used for horticultural purposes might, in many cases, be used with advantage on the first discovery of a fire, when a very small quantity of water, promptly applied and accurately directed, might prevent serious mischief. Garden-syringes are made either to throw water in a compact jet, from a simple nozzle with one perforation, or to distribute it in the form of a shower, from a rose perforated with a number of small holes. In the latter case it is usual to add a nozzle of comparatively large bore, through which water is allowed to enter, although a self-acting valve prevents it from returning the same way. Several different caps may be fitted to the same syringe; those for throwing jets having the injection and ejection nozzles side by side, while those for producing showers have the injection nozzle in the centre of the rose. Syringes may also be applied with advantage in washing carriages, cleaning windows, and for other useful purposes. Mr. Baddeley has introduced many improvements in garden-syringes.

In medicine and surgery syringes of various kinds are employed in administering clysters; in injecting fluids into, or removing them from, the stomach or bladder; injecting liquids into wounds; and injecting coloured liquors or melted wax into veins, &c., in anatomical preparations. The application of the syringe as a stomach-pump is peculiarly important. In this case a flexible tube is put into the mouth of the patient, with a guard between the teeth to preserve it from injury, and a branch pipe is added to supply the syringe with liquid from a vessel, when it is used for injection, and to afford a channel for the escape of the abstracted liquid when the syringe is employed to empty the stomach. By an ingenious arrangement of valves, the same instrument may be so modified as to act equally well in either way. One method of using such an instrument is, first to inject a diluent into the stomach, and then to pump it back again, together with the injurious matter which it is desired to remove. Another plan is to inject a fluid into the stomach until an involuntary discharge takes place through the mouth, and to continue the operation until the stomach is cleansed, this being indicated by the fluid returning unchanged.

Mr. James Harris, of Plymouth, in 1822, devised a method of preserving oil-colours for painting in syringes formed of tin, or of brass tinned internally. A similar contrivance, in which the details differ from Mr. Harris's, although the same principle, that of propelling the piston by means of a screw, is preserved, has been brought into use; but tubes of very thin metal, from which the colour is expressed by collapsing the tube between the finger and thumb, without the use of a piston, have nearly superseded all other contrivances.

SYRINGE, CONDENSING AND EXHAUSTING. [AIR-PUMP.]

SYRINGIN. [LILACIN.]

SYRUPS are medicinal solutions of sugar, either in water alone, as in simple syrup, or in liquids charged with some peculiar principle of an active kind, such as senna or buckthorn, or merely grateful from its colour or fragrance, or both, such as syrup of violets. These must be of a proper consistence, either by having a suitable quantity of sugar added to the water at first, or by subsequent evaporation of the superfluous water. The former is the preferable mode, as the syrup keeps better. The purest and most thoroughly refined sugar should be employed, and generally in the proportion of two parts of sugar to one of fluid. Less sugar is needed where *acid* syrups are to be made, as in syrup of mulberries, and still less where *vinous* syrups are made. When made, the syrup is to be preserved in closely-stopped bottles, and kept in a cool place, the temperature of which never exceeds 55° Fahr.; but, with every precaution, fermentation is apt to occur, particularly if warm or boiling water has been employed to extract the vegetable principle, when cold water is most appropriate: so also with the syrup of poppies, which, when given in a state of fermentation to children, too often aggravates the disorder of the bowels it was intended to alleviate. To counteract the tendency to fermentation, rectified spirit is enjoined to be added to the sugar—an expensive proceeding, quite needless when cold water only is used in the preceding stages. When too little sugar is used, fermentation is still more apt to occur; when too much, the excess crystallises. Syrups are more used for their fragrance or colour than for their medicinal properties, which few possess to any important extent, except syrup of poppies, the cause of a larger mortality among children, especially of the poor, than any other drug: see Christison on 'Poisons,' and Reports of the Registrar-General, almost weekly, especially 17th Nov., 1860. The number of syrups might well be diminished.

SYSTEM (Astronomy). This term is applied to every theory of the disposition and internal arrangements of the solar system, or of the material creation generally. Thus we have the system of Ptolemy, of Copernicus, &c. Perhaps a short description of the distinctive characters of the different systems may be useful in a work of reference.

Ptolemaic.—The earth is an absolutely fixed centre, and the planets revolve in circles about centres which themselves revolve round the earth.

Copernican.—The sun is a centre, round which the planets revolve. Some of the machinery of the Ptolemaic system is retained.

Tychonic.—The sun is a centre of motion to all the planets, which revolve round it, while the sun and planetary orbits are carried together round the earth as a fixed centre.

Semi-Tychonic.—The sun is a centre of motion to Mercury and Venus, as in the Tychonic, and the motions of the other planets are as in the Ptolemaic system.

Newtonian.—There is no fixed centre, the sun only approximating to that character from its greater magnitude. The orbits of the planets are approximately represented by ellipses, exactly by ellipses of which the elements vary.

The Newtonian system is frequently called Copernican, from its rejecting what Copernicus rejected; but it is far from receiving all that Copernicus received. The introduction of the ellipse is due to Kepler. We have not included the system of Des Cartes [VORTICES], because it has reference to physical causes, and contains no peculiarity of arrangement. [PTOLEMAIC SYSTEM; BRAHE (TYCHO), COPERNICUS, and NEWTON, in BIOG. DIV.; PRINCIPIA; GRAVITATION; SOLAR SYSTEM, &c.]

The term system is also applied to the subdivisions of the solar system: thus we have the terrestrial, Jovial, Saturnian, Uranian systems.

SYSTEM (Mathematics), a word little used: we hear sometimes of a system of equations, or a system of curves or surfaces; the former meaning a set of equations which are related to each other in the same problem, the latter a class of curves or surfaces which are connected by any law.

SYSTEM, in the musical language of the Greeks, had the same signification as the word Scale has in modern music. [SCALE.] Each of the many genera of the ancients was a system in itself, if we may venture to assert anything positively concerning a subject which is involved in much obscurity. [GENERA.]

In modern music the term *System* is applied to any theory of harmony, that is to say, of the origin of chords, and of the manner of treating them in composition. Thus we have the systems of Rameau, Tartini, Kirnberger, &c. The system of Guido d'Arezzo, or that ascribed to him, included the elements of our present mode of notation; also the division of the scales into hexachords, and a mode of solmisation founded on such division. [GUIDO D'AREZZO, in BIOG. DIV; HEXACHORDS.]

SYZYGIES AND QUADRATURES. The syzygies of a planet or of the moon are those points of its orbit at which it is in conjunction or opposition with the sun: the quadratures are the precisely intermediate positions. Thus at new and full moon the moon is in syzygies; at half moon, in quadratures.

T

T is the thin (tenuis) letter of the dental or palato-dental series. For the various forms of the symbol by which it is represented, see Alphabet. The chief changes to which the letter is liable are as follows:—

T is interchangeable with *c*, as Lat. *nuc* (*nux*), Eng. *nut*. [See C (§ 6).] The resemblance of these letters in Latin manuscripts is so close, that it is often difficult to distinguish them. Hence there is much uncertainty in the orthography of many words in that language. Yet there is no doubt that *contio*, an abbreviation of *conventio* (*coventio*, in the sense of *contio*, actually occurs in the so-called bacchanalian inscription), and *nuntius* or *nountios*, an abbreviation of *novi-ven-tius* (compare *nov-i-tius*), should be preferred to the forms *concio*, *nuncius*, which are commonly found in English editions of Latin authors.

T interchangeable with *d*. [See D.]

T interchangeable with *th*, whether as pronounced in *thin* or in *the*. Thus the Latin *t* corresponds for the most part to *th* in English, as *tu*, *tres*, *tenuis*, *tundo*, *tum*, *trudo*, *torqueo*, *pater*, *mater*, of the former language, severally correspond to *thou*, *three*, *thin*, *thump*, *then*, *thrust*, *throw*, *father*, *mother*, of the latter. As regards the pair of words, *torqueo*, *throw*, it is worth observing that they both have a double meaning—*hurl* and *twist*. Even the termination of the third person in the Latin and old English verbs presents the same analogy, as *amat*, *loveth*.

T, or PT, interchangeable with *p*. [See P (§§ 7, 8).]

T interchangeable with *s*. [See S.]

T interchangeable with *l*. Thus the Latin words *lingua* (also *dingua*), *lacr-uma* (also *dacr-uma*), *lacerare*, *ligare* (also *dicare*), severally appear in English as *tongue*, *tear* (subst.), *tear* (verb), *tie*. *Mitis* of the Latin is allied to *mild* in English. Compare also the Latin *ali-quod*, &c., with the German *et-was*, &c. [See L.]

T interchanges with *nd*. This change is perhaps not common. Examples are—Lat. *et*, Germ. *und*, Eng. *and*; Lat. *sed* or *set*, Germ. *sond-ern*, Eng. *sund-er*, *sundry*, &c.; Lat. *fund-us*, Eng. *bottom*.

T interchangeable with *n*. Thus from the Icelandic perfect participle *haldin* we have a masc. nom. *haldinn* (for *haldins*), and a neuter nom. *haldit*; for it is an error to treat the *t* of this last form as a neuter suffix, seeing that neuters never differ from masculines except by curtailment. This change of *n* with *t* and *d*, accounts for the varied forms of our English participles, *holden*, *molten*, *melted*, *felt*, and the Scotch forms in *it*, as *abasit*.

T disappears from the beginning of words before *l*, as in *latus*, the so-called participle of *fero*, but in fact connected with the Latin *tollo*, and the Greek *τλη-μι*, *ταλ-ας*, *τολ-μη*. An older form of *latus* was perhaps *tlatus* or *stlatus*.

T in the middle of words, when flanked by vowels, often disappears. Thus the Latin words *pater*, *satis*, *vita*, *amatus*, *amata*, reappear in French as *père*, *sez* (in the compound *as-sez*, from *ad-satis*), *vie*, *aimé*, *aimée*. Similarly, from the map of Gallia, viewed in connection with the map of France, may be derived the examples, *Autura*, *Eure*; *Caturiges*, *Chorges*; *Catalauni*, *Châlons* (sur Marne).

T at the end of words is frequently dropped. Of the omission of a final *t* in pronunciation, the French language has numerous examples, as in *et*, *fait*, *est*, &c. It is very probable that a final *t* has in this way disappeared from the third person singular of many tenses in the French verb, as *il aime*, *il aimera*, *qu'il finisse*, &c. In the interrogative form *aime-t-il*, the interposed *t* really belongs to the verb, and owes its preservation in this form to the fact that a vowel follows. It is an error to attribute the insertion of the letter to the necessity of avoiding an hiatus. Even the Greek language drops this *t* in the suffix of the third person, as in *τυπτει*, *ετυπτε*, for *τυπτετι*, *ετυπτετε*. Compare the middle forms *τυπτεται*, *ετυπτετο*.

Ti before a vowel is often changed to a sibilant represented by *s*, *sh*, *ch*, &c. Thus from the Latin *faction* (*factio*) are derived the French *façon* and the English *fashion*. So *avaritia*, *malitia*, *vitium*, became in French and English, *avarice*, *malice*, *vice*.

TABERNACLE, THE (אֹהֶל מוֹעֵד, and sometimes, chiefly in *Numbers*, אֹהֶל הָעֵדוּת, or מִשְׁכַּן הָעֵדוּת; LXX., *σκηνή*, or *σκήνωμα τοῦ μαρτυρίου*; that is, the tabernacle of the testimony), was a sacred building, partaking of the nature of a tent, which was set up by the Israelites in the wilderness for the worship of God, and carried with them in their journeys. Hence it is called by Jewish writers "a portable temple" (*ἱερὸν φορητὸν*, Philo, 'Opp.,' ii., p. 146, *ναὸς μεταφερόμενος καὶ συμπερινοστῶν*: Joseph., 'Antiq.' iii., 6, 1). It was made under the direction of Moses, in exact conformity to a pattern shown to him by God when on Mount Sinai. (Exod. xxv. 40; xxvi. 30, &c.; Heb. viii. 5.)

Without doubt temples existed in Egypt, and possibly in Palestine, before the period of the exode; but the Israelites were not in a position to raise an edifice while on their migration to the promised land. They therefore were directed by Moses to construct a tabernacle. The description of it is sufficiently given in Exodus xxvi; but the translation of badgers' skins for the covering, xxv. 5, and xxvi. 14, is an unfortunate one, as the badger does not exist in south-western Asia, and would have been also an unclean animal, not likely to have been selected to have formed any part of the structure. The Hebrew word is tachash, used nowhere else except in Ezekiel xvi. 10, where it is stated to be used for the shoes of women. It has been conjectured that it implied the colour, in which sense the Septuagint and the Chaldee and Syria versions interpret it, though such interpretation has no support from the etymology, or in any of the kindred languages. There is little doubt that it means the skin of some animal. The seal has been suggested, but that is also a stranger to the region. Niebuhr and Ehrenburg believe it to have been the skin of a species of dolphin (the *Halicora Hemprichii*), which is perhaps the most likely, as the Arabs of the present day use the skin of that animal for their shoes or sandals.

Each of the sacred vessels and instruments had its appointed place in the tabernacle. Near the entrance of the outer court was the brazen altar of burnt offering, on which were presented all the burnt offerings and sin offerings which were not required to be offered without the camp. Farther on was the brazen laver, where the priests were required to wash their hands and feet before they entered into the tabernacle.

Within the Holy Place was the golden table of shewbread on the north side, the golden candlestick on the south side, and the golden altar of incense, with their instruments. In the Most Holy Place was the ark of the covenant, with its cover, the mercy-seat, the symbol of Jehovah's throne.

None but the priests were allowed to go into the tabernacle. They entered it twice a day; in the morning to put out the lights, and in the evening to light them; and also on the Sabbath to place the new shew-bread. The Holy of Holies was entered by the high-priest alone, and by him only once a year, on the great day of atonement. Of course there was a necessary exception to these rules when the tabernacle had to be taken down or set up.

The tabernacle was first set up by Moses on the first day of the first month of the second year from the Exodus, when the presence of God was manifested by the shekinah, which filled the tabernacle. Whenever the camp was at rest, the shekinah was over the tabernacle, as a cloud by day and a fire by night. The lifting up of the shekinah was the divine signal for the people to march; and when it again rested in any spot, there the tabernacle was set up, and the camp was formed around it. After the conquest of Palestine the tabernacle was set up in Shiloh, where it remained, with the ark of the covenant in it, till the latter was carried out to battle and taken by the Philistines just before the death of Eli. (1 Sam. iv. 16-21.) After seven months the Philistines, moved by the judgments of God, restored the ark, which however was not brought back to Shiloh, but to Kirjathjearim (1 Sam. vii. 1-2), where it remained till David brought it to the city of David in Jerusalem, and pitched a tent for its reception (1 Chron. xiii.-xvi.). Here it remained, with a short interruption during the rebellion of Absalom, till it was placed in the Holy of Holies of Solomon's temple. (2 Chron. v.)

We have no exact information respecting the history of the tabernacle during this period. By comparing 1 Sam. xxi., with Mark ii. 26, we learn that it was at Nob in the time of Saul. At the beginning of Solomon's reign it was at Gibeon (1 Kings iii.), whence it was taken by Solomon, and laid up in the Temple, at the time when he removed the ark. (2 Chron. v.)

The institution of the tabernacle was in perfect accordance with the spirit of the Israelitish constitution. Jehovah was the king of Israel; he had promised to be with them, and to go with them in their journeys; and the tabernacle was his abode. Here the glory which was the symbol of his presence was displayed, and hither the people came to worship him and to inquire his will, while his chosen servants (the priests) attended constantly upon him. (Ps. lxxxiv. 4-7.) When Israel was firmly settled in the promised land, and a special place was fixed on for the display of God's presence, the moveable tabernacle was superseded by the permanent temple. The New Testament refers to the tabernacle as typical of the blessings of the Gospel. (Heb. ix.)

TABERNACLES, FEAST OF (חַג הַסֻּכּוֹת, *ἑορτὴ σκηνῶν*, *σκηνοπηγία*), was the last of the three great annual festivals of the Israelites which required the presence of all the people in Jerusalem (Exod. xxiii., 16; Levit. xxiii. 34; Numb. xxix. 12; Deut. xvi. 13). Its object was to commemorate the dwelling of the people in tents during their journeys in the wilderness; and it was also a feast of thanksgiving for the harvest and vintage, whence it is called "the feast of ingathering." It was celebrated in the autumn, at the conclusion of the vintage, and lasted eight days, namely, from the 15th to the 23rd of the seventh month (Tisri, which corresponds to October). The first and last days were holy convocations, in which no work might be done, and the last was the greatest day of all the feast (John vii. 27). In the opinion of many biblical antiquarians, the feast of tabernacles properly lasted only for seven days, the eighth being peculiarly "the feast of ingathering." (Nehem. viii. 18.)

This feast lasted longer than either of the other great feasts; it was kept with greater demonstrations of joy, and more sacrifices were offered during its continuance. (Levit. xxix. 12-38.)

During the feast the people dwelt in booths, which were made on the tops of their houses (Nehem. viii. 16). These booths were made of the leafy branches of certain trees, which are mentioned in Levit., xxiii. 40, and include the citron, the palm, the myrtle, and the willow, though in Nehem., viii. 15, the olive and the pine are also mentioned. These booths were meant to represent the tents in which the Israelites dwelt in the wilderness. In the sabbatical year, the law was read in the presence of all the people at this feast. (Deut. xxxi. 10-13; Nehem. viii.)

Like many others of the institutions of the Mosaic law, the feast of tabernacles was neglected during the period from the settlement of Israel in Palestine to the Captivity. It was revived in the time of Ezra and Nehemiah. (Nehem. viii.)

Plutarch (Sympos. iv. 6) gives an account of the feast of tabernacles, which he supposed to be in honour of Bacchus.

The later Jews have added other ceremonies to those which are assigned to this feast in the law. 1. They carry a citron in the left hand, and a bundle of branches, namely, one of the palm-tree and two of the willow and myrtle, in the right, with which they walk in procession round the reading-desks in the synagogues, singing Hosannahs. This ceremony, which is repeated seven times on the seventh day, is said to be in commemoration of the taking of Jericho by such a repeated procession round its walls. (Joshua vi.) 2. On each of the seven days of the feast they pour out a libation of water. They assert that this was done anciently before the altar at Jerusalem, with water brought from Siloa. 3. They assert that lights were burnt in the court of the women on the first evening of the feast. These lights were in large golden candlesticks, and their brightness was visible over all the city.

TABES. This word belongs to a period in the history of medicine, when nosologists were less informed than they now are of the true nature of many diseases; and, instead of classifying these according to their essential characters in reference to the single standard of healthy function, selected and arranged such signs and appearances only as were sensibly manifest to the observer, or were described by the patient. The nomenclature founded on this arrangement consisted in naming by uninterpreted symptoms: it involved many breaches of natural affinity, and gave great opportunity for empirical practice. Thus a cough, a dropsy, a palpitation of the heart, would be spoken of as individual diseases; whereas they may on the one hand be joint symptoms of a single malady (as imperfect valvular action of the heart); or, on the other hand, taken singly, each would be but a sign, common to many disorders, which might have no other feature of resemblance, and might require even opposite treatment. Such a name is "tabes," and under it are isolated certain symptoms, afforded by the nutritive functions in various conditions of unhealth: the acceptation of the word being a "cachexia (or state of chronic ill-health) attended by emaciation;" in which sense it is synonymous with the words "atrophy" and "marasmus."

TABES MESENTERICA. This name is applied to a particular slowly-disorganising affection of the mesenteric glands, and expresses the marked emaciation which attends the disease. It is through the mesenteric glands that the nutritive products of digestion are transmitted in their course to the great current of the circulation; and any disorder which destroys or obstructs these organs must, in proportion to its intensity, affect their function, and derange the process by which healthy materials of renovation should constantly be commingled with the blood. Hence in part arises the loss of flesh in this form of tabes; but the direct hindrance of nutrition which the disease involves is not the sole, though an important cause of the symptom; for the general ill-health, of which tabes mesenterica is but a part, and other co-existing complaints, usually co-operate in producing it.

The disease is one among many manifestations of scrofula; and is essentially the same to the glands of the mesentery as those obstinate glandular enlargements of the neck, with which the eye is more familiar, are to their region of the body. From difference of position and of relations it includes other symptoms and graver consequences than theirs; but it originates in the same constitutional tendencies, and follows the same general progress. It belongs, like other forms of scrofula, to early life; the ordinary period of its invasion being from the second to the twelfth year. In the Hôpital des Enfans, of Paris, children are received from a year after birth till the completion of sixteen years of age; and M. Guersent, the physician of this institution, states that the disease exists among those admitted in the proportion of 7 or 8 to 100; and that it is more frequent among female children than among males.

The morbid appearances on dissection of fatal cases are, a more or less complete transformation of the glands into tubercular masses, with various consequent or coincident diseases of the adjoining organs. The glands appear at the commencement of the complaint to be the seat of a feeble inflammatory action, under which they merely swell and become preternaturally reddened with blood; but this stage of simple congestion soon induces a further change, in which the characteristic product of scrofulous inflammations becomes deposited in the tissue of the gland. The dull white granular tubercles, by which the infiltration commences, are gradually multiplied in number or increased in volume; and, in like proportion, the glandular substance itself is absorbed to make room for the encroaching disease, till at length a rounded tubercular mass results, varying for each tumour from the size of a marble to that of an egg. In a still more advanced condition of the disease suppuration frequently occurs in these tumours, and they are then seen to contain the cheese-like matter of softened tubercle mixed with pus. The abscess so formed excites irritation in its neighbourhood; the folds of peritoneum covering it become glued together, and its progress occasionally extends to discharging itself into the nearest intestine, or through the external integument of the abdomen. A certain amount of inflammation of the peritoneum, with adhesions and effusion of serum (ascites), attends these latter stages; and some inflammation and ulceration of the mucous membrane of the intestines are likewise frequently found.

For a particular account of its causes the reader may refer to those of SCROFULA. Original weakness of constitution, shown in general susceptibility to the impressions of disease, in slowness and insufficiency of reactive and reparative power, is the groundwork of these, and constitutes the main peculiarity of the so-called *scrofulous diathesis*. But this weakness may, where inborn, be aggravated, or, where naturally absent, be artificially produced by a variety of depressing causes; by insufficient or unhealthy food, by neglect of cleanliness and exercise and clothing, by residence or constant occupation in ill-ventilated buildings, by exposure to cold and damp: all of them influences to which the young of the poor in crowded towns are exposed, and with which too frequently an inherited predisposition powerfully co-operates. Derangement of the bowels must be considered the most freuqent special cause of this particular form of scrofula; the irritations, inflammations, and ulcerations of their mucous surface (of which such full evidence is given in the state of the tongue and excretions, and in the tympanitic abdomen) excite corresponding conditions in the absorbent glands connected with them (precisely as a lesion of the hand irritates the glands of the axilla), and the inflammation so beginning takes a course determined by the peculiar constitution of its subject.

As regards symptoms, it may be observed that in its earliest stages the disease has no signs by which it may be certainly distinguished; that it is not till the glands are so enlarged as to become sensible externally that their affection can be positively declared. The early symptoms are those of the intestinal disorder or irritation, which is acting as a cause of the disease: capricious appetite, irregular and unhealthy stools, flatulence or occasional vomiting, loaded tongue, foul breath, harsh skin, sallow complexion, and loss of flesh, with an accelerated pulse, may have existed for some time, before enlargement of the abdomen attracts notice. It will then usually be found that steady pressure on this part causes uneasiness or pain. As the growth of the glanular tumours continues, the signs of intestinal disease become more marked; diarrhœa with mucous stools, increased emaciation, frequent pulse, and evening accession of fever, marking this stage, in which the tumid abdomen contrasts remarkably with the wasted limbs and shrunken wan face of the patient. Finally, hectic fever with exhaustive diarrhœa, or acute abdominal inflammation, or the progress of the constitutional disease in other organs, or absolute starvation (atrophia), terminates life.

The treatment of tabes mesenterica must be in accordance with the general rules for management of scrofula, and consists in that modified tonic system, to which the name of "alterative" is given. [SCROFULA].

TABLATURE, in Music, is the old mode of notation for instruments of the lute kind. For this purpose six parallel lines were used, each representing a string, on which were placed letters referring to the frets on the neck of the instrument. The time, or duration, of the notes was marked by characters over the letters, answering to the minim, crotchet, &c., and often, as by Mace, in his 'Musick's Monument,' by the notes themselves. There were different systems of Tablature; but the subject is not now worth the trouble which a knowledge of it would demand.

TABLE.* By a table is meant a quantity of information arranged under heads in such manner that by looking under one head the general disposition of the whole points out where to look for the matters of information connected with that head: the object being an immediate power of reference to any one fact or result without the necessity of looking at others. In any astronomical table, the matter by which we enter the table to look for other matter is called the *argument;* that which is found by means of the argument has no distinct name; we might call it the *tabular result*. It would be useful to generalise these terms. Thus in a table of contents, the number of the page or chapter is the argument, and the abstract of the matter contained is the tabular result: in an alphabetical index the principal word, found by means of its first letter, is the argument; and the number of the page in which the matter is contained is the tabular result. It is, unfortunately, useless to say much on any tables except mathematical ones. Works containing collections of facts, in which the tabular form ought to be frequently used, are in most instances altogether free from them: and as to indexes, the art of making them seems to be lost; very few books, except those on law, have anything deserving the name. The reason is obvious enough: where proper information is not given, the table shows the spot where it ought to be, *vacant;* and a good index points out not only what *is* in the work, but also that which *is not.* For instance, to take a table which we should only have inserted in this article in mere illustration, the 'Numerorum Mysteria,' of Peter Bungus (2nd ed. Bergomi, 1591) is a table of numbers. The argument is the number sought, the tabular result is a list of the hyper-arithmetical properties of the number. Thus, turning to 666, we find all the modes of interpretation which a zealous adherent of Rome could give, including Martin Luther, who satisfies the equation, both in Latin and Hebrew, as perfectly as the average run of solutions. But 667 is not in the table; so that we see it has no mystery about it.

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* Throughout this article all works which we describe from actual inspection have the dates uninclosed: all works which we take from others have the dates ( ) in parentheses.

When the matter sought for is found by one argument only, the table is said to be of single entry; when by two, of *double entry.* Thus the common multiplication table is one of double entry; and so is any chronological table which consists of more than one column.

A table is, of course, used after the manner of a dictionary; and the chief plague attending the use is the constant turning of the leaves. The trouble which this gives may be lessened by cutting off successive lengths on the right-hand margins, as is done in the indexes to ledgers, and in other works of reference. We have tried this on a table of logarithms (of the Useful Knowledge Society, 1839) taking the common logarithms, and making the cuttings so as to show a little bit of every alternate leaf. Enough of the leaf is shown to enter four figures of the primitive with which it begins in black ink, and four figures of the logarithm in red ink. The saving of trouble is so decided that no person who has experienced it will ever again allow a table *which he frequently uses* to be without this contrivance. So soon as the advantage is understood, tables will have the proper references printed on the proper parts of the margin, the binder being left to cut away the supervening strips. The same object might be gained by protruding slips of vellum pasted down the margin, if the boards of the book were made to extend beyond the margin sufficiently to protect the slips; this also we have tried with good effect. We can assure those who are constantly in the habit of using logarithms that they may make this hint give a greater facilitation than has ever been proposed since the time when Briggs brought forward his modification of Napier's system.

Mathematical tables may be divided into *conclusive* and *subsidiary:* conclusive, such as the table of squares, in which the tabular result is the object of the reference; subsidiary, such as the table of logarithms, in which the tabular result only facilitates the object. Conclusive tables can be easily used by those who want them but seldom: subsidiary tables are not much used, except by those who want them more frequently. The reason is that a subsidiary table which is not often wanted has its *modus operandi* forgotten between uses; or at least the possessor feels a want of practice, and a necessity for referring to the directions, to be sure of his result. The best thing to be done, when a person first takes to a new subsidiary table, is for *himself* to write in the book *his own* account of the method of using it, so soon as he has learnt it, with some examples. This reference he will find, on future occasions, to be more suggestive to his memory than anything which the writer of the book has said or could have said.

The method of printing mathematical tables is usually defined so closely by the nature of the subject, that no remark is necessary except on the type. The numeral characters, up to about the year 1785, used to be smaller in the body than those now constructed, with distinguishing heads and tails. Dr. Hutton, we believe, first employed the character in which all the numerals are of the same depth, the heads or tails being compressed into the body. This very disadvantageous change was adopted by the type-founders, but for a long time only in England: the consequence was that the superior legibility of the ancient and of the modern continental tables was matter of common remark among those who had to use them. Another circumstance which contributed to this result was the introduction of numerals with thick and thin parts, the superior elegance of which was supposed to be a recommendation. The consequence was, that in many English tables it was difficult to distinguish 3 from 8, and 9 or 6 from 0. Of late years however, many works have been published which have used the old type, both as to heads and tails and uniform thickness;[*] and their decided superiority over tables of the Huttonian character, even of much larger type, is pretty generally admitted. This is a point of great importance: for any circumstance which produces a wrong result upon the computer's paper is equally to be deprecated, whether it be an error in the formula used by the author of the tables, or an incorrectness of the printer or reviser; and in like manner a given amount of tendency to error is of the same bad consequence, whether it be due to the mathematician or the type-founder. This is not true of works of theory or reasoning: it may there be the fault of the reader if he do not correct a mere slip, whether of the author or printer; but in works of tabular reference *all the parties to the result are of equal importance.*[*]

The restoration of the old numerical type, namely, that in which all the figures except 0, 1, 2, have a head or a tail, and in which the thickness does not vary sensibly from one part to another, was adopted and recommended by the Astronomical Society at the end of 1842; but it had previously been used by Mr. Baily in his detail of the Cavendish experiment, which forms one volume of the Memoirs of that Society. The writer of this article, who first suggested the revival of the old figure (and caused it to be employed in Taylor and Walton's five-figure logarithms, in their reprint of Barlow's tables, and in his own work on Arithmetic, before any one else had used it), is decidedly of opinion that one more change is yet wanting, the substitution of dull and rather dark paper for the bright and shining material now in general use, which dazzles the eye too much. Tables should not be hot-pressed, and not even pressed at all. The mischiefs of pressure are two-fold; first, the smooth surface thereby created makes the page a kind of mirror, which has a bright image in one place, whereas rough paper dissipates the light equally in all directions; secondly, the other side of the leaf shows through much more after pressure than before. It is also a mistake to suppose that great blackness in the ink, combined with great whiteness in the paper, is favourable to the reader. Every increase of the contrast, over and above what is necessary to perfect legibility, is injurious to it: jet upon snow would in time destroy the strongest eyes. Of all the things which are meant to be read, a black monumental inscription on white marble in a bright light is about the most difficult: one would suppose, to look at our specimens of expensive printing, that such an inscription was the model which it was intended to imitate, and if possible to surpass. We are satisfied, after many trials and comparisons, that a dull paper, of a whitish-brown character, too thick to be seen through, and an ink which is of a dull-brown black, as it were the very deepest shade of the colour of the paper itself, are the things which are permanently agreeable to most eyes. Those who try it should remember that the first page read is not so good a test as the hundredth.

One of the most legible books we know of is the trade edition of Gibbon's 'Decline and Fall,' &c., in twelve volumes octavo, London, 1820. It is considered by the booksellers themselves to be very badly executed. But printers and publishers are too much in the habit of forgetting that a book is a book and not a line engraving. They look at the page as a whole, and if the individual lines stand out and make their separate existences too perceptible, they pronounce it ugly. Accordingly, the uglier they hold it to be, the more legible the reader will pronounce it. We have seen more than one printer and publisher hold a page at such a distance from his eye as made it impossible for him to read it, as a means of judging of the *general effect.* Surely a printed page is meant to be a congeries of *particular effects,* each as distinct from the other as possible.

We regret to see that, just as we have nearly abandoned the use of the thick even-sized figures, the Germans are taking strongly to them. Most of the modern German tables have these illegible characteristics.

Since the invention of logarithms, the appetite for tables has not grown with the progress of mathematics. Calculation by logarithms is so convenient for ordinary purposes, that many persons who are even well versed in mathematics are not aware how much assistance they might derive in particular cases from the various tables which have been published. The list which we mean to give does not profess to be a bibliography of tables, but will nevertheless give information on the subject to all who are not particularly given to mathematical bibliography.

We may divide mathematical tables into general and special; the first consisting of purely arithmetical and trigonometrical tables, and also tables of logarithms. The special tables are those which are used in the higher parts of mathematics, in commerce, navigation, astronomy, meteorology, &c. We may further divide tables into tables of facts and tables of mathematical results. All sciences have their tables of facts; thus the raw observations of astronomy, magnetism, and physics in general are frequently tabulated: with these we have comparatively little to do; since they are rather the materials for the formation or verification of other tables, than of primary use as tables.

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[*] In the new series of the 'Nautical Almanac,' the heads and tails first re-appeared, but the swelling of the type was not rejected. The works in which the old legibility was first completely restored were, so far as we know, the tables of logarithms (four and five figures), and the reprint of Barlow's Tables (Taylor and Walton), the six-figure logarithms (Longman), and Lieut. Raper's 'Elements of Navigation.' Thus it stood when the 'Penny Cyclopædia' was published. The legible figures are now common enough in England: but Germany is infested with the illegible ones. The swelling type has been rejected in the 'Nautical Almanac,' which is now as legible a tabular work as exists, as to both print and paper.

[*] So we said in the 'Penny Cyclopædia': we now incline to think that *the printer is the most important of all.* One of his errors may be equal to many of the author's. For instance, in Chernac's table a line fell out, probably just before press: it was put in again at the top of its compartment instead of at the bottom. The consequences were 26 gross errors, of a far worse kind than the author could have made, unless he had tried. Burkhardt found but 10, besides this set, in the whole book; and of these one was only 23 × 19 instead of 19 × 23, and two others were clearly due to the printer at press. Chernac's work has 1020 large quarto pages full of figures, or lines of equal importance.

Of simple arithmetical tables we may notice the following:—

§ 1. *Tables of multiplication.*—The oldest we know of is as follows:— Tabulæ Arithmeticæ ΠΡΟΣΘΑΦΑΙΡΕΣΕΩΣ[*] Universales . . . . E Museo Johannis Georgii Herwart ab Hohenberg V. I. Doctoris. Munich, 1610, folio. This table goes up to 1000 × 1000; each page taking one multiplier complete. There are then a thousand odd pages; and as the paper is thick, the folio is almost unique in thickness. There is a short preface of seven pages, containing examples of application to spherical triangles. It is truly remarkable that while the difficulties of trigonometrical calculation were stimulating the invention of logarithms, they were also giving rise to this, the earliest work of extensively tabulated multiplication. Herwart passes for the author, but nothing indicates more than that the manuscript was found in his collection. The book is excessively rare; a copy sold by auction a few years ago was the only one we ever saw.

There have been several others of great extent, but they are scarce. Hutton's 'Tables of Products,' printed by the Board of Longitude, 1781, go up to 100 times 1000, but have not the reputation of correctness. An anonymous table, London, 1775, which goes up to 10,000 × 10, is 'Tables of Products . . . London, printed for J. Plummer.' But Riley's table, published in the same year, under exactly the same form, is 'Riley's Arithmetical Tables . . . . London, printed for G. Riley.' It is imperfect in all the copies we have seen, ending abruptly at the multiplicand 5280. The numerals are of the same form and size as in Plummer, but the headings and lines are different. We suspect that some writer of more than usual research on the quarrels of authors, or some hunter of old injunction[†] cases, might find something about the history of these two books. The type is clear, and the tables are very useful.

Dodson's 'Calculator,' London, 1747, has the same as the last up to 1000 × 10, not so conveniently arranged. But by far the most powerful table of this kind is Crelle's 'Rechentafeln,' Berlin, 1820, in two thick 8vo volumes. This contains every product up to 1000 times 1000, so arranged that all the multiples of one number are seen at the same opening of the book. All who have used this table know how to dispense with logarithms in many cases with great advantage. There is no table which we so much desire to see reprinted in this country, with a few alterations, which would render it more commodious. Another edition was published by Dr. C. Bremiker, Berlin, 1857, folio; but we are told that other copies bear the date (1859), and, we believe, no editor's name. Each page here contains the 999 multiples of two numbers; giving 450 pages of tables. This edition is very convenient, and of very comfortable type and paper. An anonymous Table, Paris (1794), goes up to 1000 × 103; and another, Paris (An VII.), the same; a third, Versailles (1825), the same, with many meteorological tables added. Schubler's 'Rechnung's Lexicon,' Nuremberg (1739), goes to 2400 × 100. Oyon's Table, Paris (1824), goes to 509 × 500; that of Cadet, Paris, 1801 or 1802, An X, to 10,000 × 100. This work of Cadet was intended for a *ready reckoner and percentage table.* Each number from 1 to 10,000 has its first hundred multiples in one folio column. Citizen Cadet was a tax-gatherer, and saw that, in a decimal system, a raw table of multiplication is a *Barême*, or ready-reckoner, quite complete. Accordingly, the title of his book is 'Tarifs des Centimes au franc, ou Tables de multiplications et comptes-faits pour la répartition des contributions, et pouvant remplacer, dans le systême décimal, les anciens comptes-faits de Barême.'

Bretschneider, 'Producten-Tafel,' Hamburg and Gotha, 1841, goes up to 100,000 × 10. There is a compression of this kind: in finding, for example, the multiples of 62873, the reader must look into the page headed 2800, and there, in one part of the page, opposite to (6) 28, he finds the first three figures, and in another part, opposite to 73, the last three figures. The first part, belonging to 628, is repeated twice, once for the cases in which the following numbers are less than 50, and once for those in which they are above it; and an asterisk in the last part of the table occurs when it is necessary to add a unit to the preceding figures. This arrangement brings the table into ninety-nine pages octavo, and is very ingenious; but there is more risk of error in using it than we like. Again, multiplying five figures by one is not so difficult an operation that it need be avoided by using a table which requires us to look attentively at three distinct things, after turning pages. Lambert's table, 1770, presently mentioned, contains the nine multiples of sin x for every degree, to six figures; and multiples of primes to those of 313. Pohlman's Table, 1813 (2nd ed.), contains the first nine multiples of all numbers up to 1000. We have heard of another work of Crelle, 'Erleichterungs Tafeln,' in oblong folio, giving all numbers under 10,000,000, with their nine multiples, but with an arrangement not easily nor safely used. There is a double process, as in Bretschneider.

In the Royal Society's Library is a table by J. J. Centnerschwer, 'Neu-erfundene Multiplikations-und-quadrat-Tafeln,' Berlin, 1825. The earliest table we have seen mentioned (by Lipenius) is Thomas Finck, 'Tabulæ Multiplicationis ac Divisionis,' Copenhagen (1604), oblong form. There is also, by the same author, 'Tabulæ quotidiano numerandi usui accommodatæ,' Copenhagen (1615), 16mo.

As Finck is an author of some interest in the history of tables (as will presently appear), we have made some inquiry about these works,[*] and we find that they are not in the library at Copenhagen; but that Mollerus ('Cimbria Litterata,' vol. iii., p. 254), gives them as follows. It seems they were not intended for scientific purposes:—

'Tabulæ Multiplicationis et Divisionis, seorsim etiam Monetæ Danicæ accommodatæ,' Hafniæ (1604), oblong folio.

'Tre Tabeller, indrettet til daglig fornöden Regning.' (Three tables accommodated to necessary daily accounts). Copenhagen (1615), 16mo.

Under this head we ought to mention John Bernoulli (the younger), 'Sexcentenary Table,' London, 1779, and Michael Taylor's 'Sexagesimal Table,' London, 1780, intended to save the use of logistic logarithms; the former having 10′ for the first term, and the latter 1°. Both were published by the Admiralty. In the day of sexagesimals, tables of multiplication were common in which the products were converted sexagesimally; as in Orontius Finæus, 'Arithmetica Practica,' Paris, 1555, in which is a table up to 60 × 60. But the multiples of 46, for example, are 0′ 46″, 1′ 32″, 2′ 18″, &c. The bibliographer should remember that when a sexagesimal table is pasted into a copy, it does not follow that it formed part of the work: owners often pasted in a table from another source.

Under the head of Multiplication, we must notice tables of QUARTER-SQUARES. The earliest we have seen (and we believe the earliest known to exist) is that of A. Voisin, Paris, 1817, 'Tables de Multiplications,' &c., 8vo, containing quarter-squares of numbers up to 20,000. Leslie reprinted this table up to 2000, in his 'Philosophy of Arithmetic' (2nd ed.), 1820, as (according to Mr. Laundy) did Galbraith, as far as 3149, in the second edition (1836) of his 'Mathematical Tables,' J. M. Merpaut, 'Tables Arithmonomiques,' Vannes, 1832, gave quarter-squares up to that of 40,000. But the largest and most valuable set of these tables yet published is that of Mr. S. L. Laundy, a London actuary, 'Table of Quarter-Squares,' 1856, 8vo, which goes to 100,000, and is beautifully printed. Colonel Shortrede, one of the most energetic of tabulators, has computed this table to 200,000, but has not published it, though we understand he intends to do so. We suggest to him to publish the second half first.

§ 2. *Tables of Division and of Prime Numbers.*—Fr. Schooten, in book v. of his 'Exercitationes,' 1657, gave all the primes under 10,000. Gruson, 'Pinacothèque,' Berlin, 1798, gives for all numbers under 100, or primes under 400, the quotient and remainder of every number under ten times the divisor, by inspection: also, primes and lowest divisors up to 10,500. Lidonne, 'Tables de tous le Diviseurs,' &c., Paris, 1808, gives the divisor of all numbers up to 102,000. The original edition of Barlow's Tables gives the factors of all numbers up to 10,000 and a register of prime numbers up to 100,103. Chernac, 'Cribrum Arithmeticum,' &c., Daventriæ, 1811, gives the prime numbers up to 1,020,000, and all divisors of numbers not divisible by either 2, 3, or 5. Burckhardt, 'Table des Diviseurs,' &c., Paris, 1817, gives the prime numbers up to 3,036,000, with the lowest divisor of each number when not either 2, 3, or 5. These useful works are now rare. Anjema's 'Tabula Divisorum,' Leyden, 1767, goes up to 10,000, and Pigri's Table, Pisa (1758), which Chernac had never heard of, the same. Anjema enters *every* divisor: thus, 2 is entered as having two divisors, 1, 2. He also separates those less than the square root from the others by a hyphen; and where the number is a square, the root has a hyphen on both sides. Krause, Jena and Leipsic (1804), has primes and factors up to 100,000. J. Neumann, 'Tabellen,' &c., Dessau (1785), has factors and primes up to 100,100.

Guldinus is said to have given tables of prime numbers, but we have neither found them nor a description of them. Thomas Branker appended to his translation of Rhonius's Algebra a table of primes and divisors for all numbers under 100,000. This was reprinted by Baron Maseres, and was appended to his tract 'On the Doctrine of Permutations and Combinations,' London, 1795, a book very easy to be obtained.

This translation of Rhonius is of London, 1668, "much altered and augmented by D. P.:" this D. P. is Dr. Pell. The table of primes, &c., to 100,000 is computed under Pell's advice and direction; and a great part, it is believed, by himself. But there is preserved in several places the title of a work of Pell which we have never seen, and which we take from Lipenius: 'Tabula decem millium difficilium Numerorum, eorum nempe omnium qui ab 0 ad centum Milliones [mille?] habent difficultates,' English, London, folio, (1666). This looks like a table of prime numbers, and the number of primes under 100,000 is about 10,000. But we must leave it to those who can see the work, if it still exist. Branker's table was reprinted in the second volume of Harris's 'Lexicon Technicum,' London, 1710.

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[*] Prosthaphæresis is a word compounded of prosthesis and aphæresis, and means addition or subtraction. Astronomical corrections, sometimes additive and sometimes subtractive, were called prosthaphæreses. The constant necessity for multiplication, in forming proportional parts for the corrections, gave rise to this table, which therefore had the name of its application in the title-page.

[†] The following gives a strong suspicion. In our copy there is a preface of fourteen pages, signed "The Editor." The late Mr. Woolgar, who made tables a special study of great depth, had a copy in which a preface of fourteen pages was signed "William Webb," whose name was also in the title. Our preface has only—"Our tables . . . . are carried to nearly twice the extent of any tables of the kind hitherto published:" Mr. Woolgar's preface has—"There have likewise been published this year by Mr. Riley, Arithmetical Tables, containing the products of all numbers from 1 to 5280, and are a set of very useful and correct tables; the errors of the press are very few, the form of them we have also thought convenient, and it is that which we have adopted." We surmise that W. Webb played Vlacq to Riley's Briggs as soon as Riley's tables were published, and that legal proceedings were compromised by an arrangement of which it was a portion that handsome mention should be made of Riley's tables in a new preface, with the editor's name.

[*] From Professor Werlauff, Royal librarian at Copenhagen, through the kindness of the late Professor Schumacher, the universal referee of those who wanted information on any point connected with astronomy, however remotely.

Vega (Octavo Logarithms, vol. ii.), 1797, gave primes and divisors up to 102,000, and further primes up to 400,000, in which Chernac found but 39 errors.

Chernac mentions primes and divisors to 10,000, in the Arithmetic of T. M. Poelius, Leipsic (1728), 8vo, reprinted in Richter's 'Lexicon Mathematicum;' primes to 101,000 in Kruger's Algebra (1746); primes to 100,000 from Kruger, in a separate work of Lambert, not the logarithmic and other tables of 1770; primes to 400,000, by A. F. Marcus, Amsterdam (1772), 8vo.

Murhard mentions the *first part* of a table (by A. Felkel) of the factors of all numbers not divisible by 2, 3, or 5, from 1 to *a hundred millions*, Vienna (1776). Chernac alludes to this table as mentioned by Krause, but had never seen it.

§ 3. *Tables of Squares, Cubes, Square Roots, Cube Roots, and Powers in general.*—Perhaps the oldest printed table of squares is that in p. 30 of Pacioli's 'Summa,' &c. [VIETA, in BIOG. DIV.], printed in 1494, and again in 1523, which, however, goes only to 100^2. Cosmo Bartoli, 'Del Modo di misurare le Distantie,' &c., Venice, 1564, has squares up to 661^2. Maginus's 'Tabula Tetragonica,' Venice, 1592, is not a separate work, but a chapter in his work on triangles, presently mentioned: it gives squares up to $10,100^2$, but not cubes. It was, however, published separately, at the same time with the work on triangles, as well as in it: the only difference being that the separate publication has its headings and explanations Italian instead of Latin. The number of so-called books, which are only chapters of other books, is large enough to make a big catalogue.

Guldinus, 'De Centro Gravitatis,' Vienna, 1635, gives the squares and cubes up to those of 10,000. The founder of the modern Encyclopædia, Alsted, 1649, gives squares and cubes up to 1000. Pell, London (1666), (Murhard), squares to that of 10,000. William Hunt, 'Gauger's Magazine,' London, 1687, gives a table of squares up to that of 10,000. A few pages of this work are Newton's. Ludolf, 'Tetragonometria Tabularia,' Frankfort and Leipsic, 1690, 4to, gives the squares up to that of *a hundred thousand;* the largest table of squares in existence, and very little known. J. P. Buchner, 'Tabula Radicum,' &c., Nuremberg, 1701, gives squares and cubes up to those of 12,000. Hutton (table in § 1) gives squares up to that of 25,400, and cubes up to that of 10,000. Lipenius mentions 'Tabulæ numerorum quadratorum decies millium,' Londini (1672), which is Pell's table, though it has not his name. It has also an English title, contains the first ten thousand squares, and also the number of pairs, triads, and quaternions (1044 in number) of figures with which a square can end. Henischius, 'Arithmetica perfecta,' Augsburg, 1609, begins with squares and cubes of all numbers up to 360. Heilbronner (p. 627) mentions a *tabula Calriana* which gives squares up to 1000^2. Detached tables of powers are given in various works. John Hill's Arithmetic, of which the seventh edition bears London, 1745, has all the powers of 2, up to the 144th, for the purpose of solving questions about chessboards and horseshoe nails. We have also the title G. C. Sartorius, 'Cubische Tabellen,' Eisenach (1827).

Dodson's 'Calculator' (§ 1) gave square and cube roots up to those of 180: Hutton afterwards gave the same up to those of 1000. Barlow, 'Tables,' London, 1814, gave squares, cubes, square roots, cube roots, and reciprocals, up to those of 10,000; the roots to seven decimal places; the reciprocals to seven significants. These were reprinted (London, Taylor and Walton, 1840), from the original, after re-examination by Mr. Farley. Tables of squares and cubes, up to those of 10,000, were reprinted from Séguin's 'Manuel d'Architecture,' with a descriptive preface, at Paris, about the beginning of the century. This table has beautifully clear figures, of 24 to the inch, of thin and even body, with heads and tails. It was this table which first suggested to the author of this article the superiority of the numerals with heads and tails, and gave rise to his suggestion to the Useful Knowledge Society, 1839, to reprint Lalande's Table in such a figure. The example is now extensively followed. Meinert's Logarithms, Halle (1790) contain squares and cubes up to those of 1000. Bochert, 'Tafeln,' &c., Leipsic (1812), goes to the square of 25,200, the cube of 1200, and the square and cube root of 1000. Beyens, Ghent (1827), goes to the square of 10,000, and the cube of 1000. Schierk, 'Tafeln,' &c., Rohn om Rheim (1827), has squares up to that of 10,000. Merpaut, in the work above mentioned, gave reciprocals up to 10,000, to nine significants.

Joncourt, 'De la Nature....de Nombres Trigonaux,' Hague, 1762, gave triangular numbers up to that of 20,000, cubes up to that of 600, and showed how to use the former in the construction of squares and square roots. As to higher powers than the third, Hutton and Barlow, in works above cited, give every power of every number up to the tenth power of 100. Barlow gives also the fourth and fifth powers of numbers from those of 100 to those of 1000. Bowditch (work of 1834, cited under 'Logarithms,' 1757) gives square roots to five decimals ·000 (·001)4·200 (·01)10·19 with tables of proportional parts.

Maseres, at the end of the tracts on Combinations, London, 1795, has reprinted Hutton's square roots 0(1)1000 to ten decimals, and reciprocals to seven. We believe that Hutton first gave them in his 'Miscellanea Mathematica,' 4 vols. 12mo, 1775. In Jonas Moore's Arithmetic, 1650, there are the squares and cubes of all numbers up to 1000, the fourth powers up to 300, and the fifth and sixth up to 200. These were reprinted in the edition of 1560.

Rogg mentions 'Art gantz neu-entdeckte,' &c., Dessau (1755), 8vo, containing the cubes of all numbers up to 100,000, or at least professing in the title-page to give the cube root of every number under a thousand millions of millions: perhaps the cubes went to that of 10,000, with a rule for the fifth figure. And here we may mention that we have been several times deceived by a title-page stating, not the extent of the table, as it ought to do, but the extent to which operations of interpolation or accession will be effective.

§ 4. *Pure Decimal Operations.*—Besides Barlow's reciprocals (§ 3), the only remarkable tables of which we know under this head are Goodwyn, 'Table of the Circles arising from the Division of a Unit,' London, 1823, and 'Tabular Series of Decimal Quotients,' London, 1823 (both anonymous). The first gives all the circulating decimals which can arise from any fraction whose denominator is under 1024; the second arranges all fractions which in their lowest terms have a numerator not exceeding 99, and a denominator not exceeding 1000, in order of magnitude, and gives their equivalent decimals to eight places. Mr. Woolgar is our authority for saying that there was a previous work by Goodwyn, 'First Centenary of concise and useful Tables of Decimal Quotients' (1818), 4to. Mr. Goodwyn (of Blackheath) was an indefatigable calculator, and the preceding tables are the only ones of the kind which are published. His manuscripts, an enormous mass of similar calculations, came into the possession of Dr. Olinthus Gregory, and were purchased by the Royal Society at the sale of his books in 1842.

R. Picarte, 'La Division réduite à une Addition,' Paris, 1861, 4to, gives, for all numbers up to 10,000, ten significant figures of reciprocal, with the nine multiples of each.

An anonymous work, 'Tafeln zur Verwandlung aller Brüche,' &c., Oldenburg, 1842, gives every fraction less than unity whose denominator does not exceed three figures, nor its numerator two, to seven places of decimals. It is arranged by numerators: that is, all fractions of one numerator are in one double page. This is a useful table. We may also mention (but not as having seen it) W. F. Wucherer, 'Beyträge zum allgemeinen Gebrauch der Decimalbrüche,' &c., Karlsruhe (1795), 8vo.

The oldest table we have found printed in English is in 'This boke showeth the maner of measurynge of all maner of lande, as well of woodlande, as of lande in the felde, and comptynge the true nombre of acres of the same. Newlye invented and compyled by Syr Rycharde Benese Chanon of Marton Abbay besyde London. Printed in Southwarke in Saynt Thomas his hospitall by me James Nicolson.' There is no date, but Nicolson's dated works run from 1536 to 1538. There is another edition (which omits the tables), printed by Thomas Colwell, who printed from 1558 to 1575. They are double-entry tables of the rudest character, for finding the number of acres in a given length and breadth, and for casting up payment at per perch, per acre, &c.

§ 5. *Pure Trigonometrical Tables.*—This section and the next form almost the whole of the article; and for a sufficient reason. The history of the trigonometrical canon, and of the logarithmic table, are constituent parts of the history of the progress of mathematics: the history of other tables has nothing to do with that progress, except only in the case of Stevinus's tables of compound interest, which, as will appear, suggested decimal fractions to their author. The bibliographical history of the early part of the trigonometrical canon is so incorrectly given, as well as ambiguously, even by the best authorities, that it will be worth while to collect the several heads, distinguishing between what we know from the books themselves and what we are obliged to take from other sources, by putting the name of an authority (of which we have usually two or three) to the latter. Much confusion has arisen from the double meaning of the word *publication* in regard to works of the century following the invention of printing, when it was applied equally to the issue of a printed book and of a manuscript. We are here only concerned with the former; and it is sometimes difficult to distinguish between the two.

The earliest trigonometrical table existing is the table of chords in the first book of Ptolemy's Syntaxis or Almagest. It is by half-degrees up to 90°, and thence by degrees. The chords are given sexagesimally, to a radius of 60°: thus, the chord of 90° is 84° 51′ 10″. The thirtieth parts of the differences are annexed: thus, the earliest table has its *differences*, and differences given by the convenient sub-multiple which would probably be thought very modern.

That Albategnius [ALBATEGNIUS, in BIOG. DIV.] had substituted sines for Ptolemy's chords,—that he had also used versed sines and tangents,—that Purbach and Regiomontanus had constructed and issued (in manuscript at least) tables of sines to two separate radii, 6,000,000 and 10,000,000—are historical facts of notoriety. Our question is, what tables were first *printed?* On the books which Regiomontanus actually printed, out of the long lists of those which he published and intended to publish (as set forth in his own 'Index Operum,' &c., printed at Nürnberg by himself), his historians, Doppelmayer, De Murr, Weidler, &c., are either not very clear, or somewhat at variance. In the vague manner in which books and their contents are frequently described by professedly mathematical writers, a good resource[*] is often found in the catalogues of general bibliographers.

The 'Tabulæ Directionem Profectionumque' of Regiomontanus were published by himself at Nürnberg, without date, probably about (1475), and were reprinted at Venice in (1485). We cannot ascertain that either of these contained tables of sines. But Hain ('Repert. Bibliogr.'), who gives their titles, gives that of the next edition, Augsburg, Ehr. Ratdolt (1490), 4to, in a fuller manner: from which it appears that there is appended to it a table of sines to minutes, in words which would imply that Regiomontanus had not given such a table in the former edition: they are, 'Tabella Sinus recti: per gradus et singula minuta divisa. Ad Tabulas Directionum Mag. Joh. de Regiomonte necessarias.' But from the description it is clear that this table does not belong to the work, since it follows even the printer's insignia. And Hain also met with it as a separate work; being, as appears from his description of the lineation, pages, &c., absolutely the same as that which was appended to the Tabulæ Profectionum. Accordingly, until something earlier or more definite is produced, we must say that the first known printed table of sines is an anonymous table, to minutes, in quarto, without date, but before 1500, stated (with *necessarias* when it ought to be *necessaria*) to be necessary to the tables of Regiomontanus, and implying that sines had not then been printed with those tables. From the next-mentioned edition of the Tabulæ Directionum (this we have seen) we should suppose that these tables were to a radius of 600,000, as in that edition, which is of Venice, 1504, 4to. In it we find a minute-table of sines, headed 'Incipit tabella sinus recti,' and with a column containing differences for ten seconds. Delambre and others mention Regiomontanus as having given the first table of tangents in this work under the name of *tabula fœcunda*. It is in the edition of 1504, and was reprinted by Gemma Frisius in his book 'De Radio Astronomico,' Antwerp, 1545. It is to degrees only, and to a radius 100,000; and is a table of cotangents, not of tangents. The Tübingen edition, 1550, also distinguishes the table of sines as an addition, in the title-page. The radius is now 60,000; but, by an oversight, the differences to ten seconds are entered from some table with a radius of 6,000,000, from which the table of 1550 was probably cut down. There is no *tabula fœcunda*. Delambre mentions an edition of the work, edited by Gauricus, in (1524), as containing a table of sines to every ten minutes: of this we can find nothing.

As yet we have no sines calculated to the now ordinary radius of 10,000 &c. Of these, the earliest we have seen (and we find no earlier ones mentioned), are those of Peter Apian in the 'Introductio Geographica.' &c., Ingoldstadt, 1533, folio. They are minute-tables to a radius of 100,000, and were reprinted the next year in the same author's 'Instrumentum primi Mobilis,' Nürnberg, 1534, folio. Apian states that they are of his own calculation, and this is to us a strong presumption that no such tables had been previously printed; for Apian was a great reprinter of the writings of others at his own press, and very unlikely to have re-calculated any table which he knew to exist already. The statement that the work of Regiomontanus on triangles, Nürnberg, 1533, folio, contains tables of sines, is incorrect: we know it from examination of two perfect copies. We can point out how the mistake arose. Lalande (Bibl. Astron.) says that the first edition of the work, Basle, 1536, has in the title-page "una cum tabulis sinuum." Now the fact is that Lalande, who had only seen the second edition (*Basle*, no date, known to be of 1561), which *does* contain tables of sines, took the liberty of presuming that the first edition was the same in contents, title, and place; in all of which he was wrong, and in the date also.

In 1542 Rheticus, the most laborious of all the table-computers, made his first appearance as the editor of a work of Copernicus, 'De Lateribus et Angulis Triangulorum,' &c., Wittemberg, 4to (Weidler and Kastner). This contains a minute-table of sines to a radius of 10,000,000, being the first-published seven-figure table: the copy in the Libri sale of April, 1861, is the only one we ever saw. The table which appeared in the following year, in the great work of Copernicus [COPERNICUS, in BIOG. DIV.], is an abridgment of the preceding; going only to every ten minutes, and to a radius of 100,000.

In 1541 appeared one of the tables which have obtained most celebrity: being the 'Tractatus Geo. Purbachii super propositiones Ptolemæi de Sinubus et Chordis, item compositio Tabularum Sinuum per Joannem de Regiomonte. Adjectæ sunt Tabulæ Sinuum duplices per eundem Regiomontanum,' Nürnberg (1541), folio (Kastner, &c.). The two tables of sines are both minute-tables, with radii of 6,000,000 and of 10,000,000. The table of tangents to every degree is repeated again under the name of *tabula fœcunda*. In a mixture of tracts by Regiomontanus, Walther, Schoner, and Purbach, headed 'Scripta . . . de Torqueto, Astrolabio Armillari, . . .' Nürnberg, 1544, 4to, is a table by Purbach, called *Tabula Gnomonica*, which is a table of tangents to the radius 1200, giving the angle to each unit of the 1200. This table is repeated in Gemma Frisius, 'De Radio Astronomico,' Antwerp, 1545, 4to, already mentioned.

Rheticus, in the meanwhile, was pursuing the route of analogy, which suggested to him the formation of a table giving *all* the ratios which exist between the sides of a right-angled triangle; by which he was led to the invention of what were afterwards called secants, to the completion of the trigonometrical canon, and to its arrangement in the form which it has ever since preserved. His rights in this matter have long been forgotten; and it is only recently that the work which established them has received any notice in modern times. (See the Notices of the Astron. Soc., vol. vi., p. 213, and Phil. Mag., June, 1845.) In 1551, the year following that in which he was placed in the 'Index' as a forbidden author, he published his 'Canon Doctrinæ Triangulorum,' Leipzig, 4to. This is a complete canon to every ten minutes, and to a radius of 10,000,000 (or, as we should now say, to seven decimals) with differences, so arranged that the matters connected with each angle also belong to its complement, in the manner so familiar to those who can use any modern table. This arrangement may be called *semi-quadrantal*, as opposed to the older *quadrantal* arrangement in which the sines are carried direct from 0 to 90°. Accordingly, the page of Rheticus has both a head and foot description, as in modern tables. So completely is he bent on the idea of a register of the proportions of right-angled triangles, that he rejects the use of the word sine. In the place of the sine and cosine he has the perpendicular and base to an hypothenuse of 10,000,000; for what were afterwards called the tangent and secant he has the perpendicular and hypothenuse to a base of 10,000,000; for the cotangent and cosecant he has the base and hypothenuse to a perpendicular of 10,000,000. The same description is adopted in his larger work, of which we shall presently speak. To the smaller work is appended a dialogue, which introduced Rheticus to his future editor; for Valentine Otho was so struck by it, that he went to Hungary to obtain information on the subject from the author. Otho relates that in the first interview, when he had hardly stated his purpose, Rheticus interrupted him with, "You are just as old as I was when I went on the same errand to Copernicus."

In 1554 Erasmus Reinhold (who had been the colleague of Rheticus[*] in teaching mathematics at Wittemberg) published the 'Primus Liber Tabularum Directionum,' Tübingen, 4to. In this work, for the first time, occurs a *canon fœcundus* (not yet called a table of tangents) carried to every minute. Both sines and tangents were computed to a radius of 10,000,000, and have differences. By the complemental degrees at the bottom of the pages, it appears that cosines and cotangents were intended. This work of Reinhold, though founded upon Regiomontanus, must not be confounded with his professed edition of the 'Tabulæ Directionum' of Regiomontanus himself, which had tangents only to every degree, and was printed several times, the last edition being in (1606). (We have not thought it worth while to catalogue all reprints.)

In (1558) (Delambre) Maurolycus published his edition of Theodosius, Menelaus, &c. (Messina, 4to), containing the three tables, that of sines, the *tabula fœcunda*, and the *tabula benefica* (as he called the present table of secants). This table goes only to degrees (except that tangents and secants are given for 15, 30, 45, 55, and 59 minutes of the last degree of the quadrant), and is to a radius of 100,000. Delambre, &c., suppose that these are the first tables of secants which were published, and they accordingly attribute the invention to Maurolycus. But we have seen that it is due to Rheticus; and Finck (presently mentioned), who lived close to these times, states expressly that Maurolycus borrowed this table from Rheticus.

In 1562 a pupil of Rheticus published a table of sines to every minute, and to a radius of 10,000,000, with differences for one second. This was Samuel Eisenmenger (or Siderocrates, as he wrote himself), in his 'Libellus Geographicus,' Tübingen, 4to. And there was, as we find stated in various quarters, a table of sines in the work on dialling of Hermann Witekind, 'Conformatio Horologiorum,' of which the first edition is said to be of Heidelberg (1576), 4to. Blundeville says they are to a radius of 100,000.

The first complete canon *to every minute* (that of Rheticus in 1551 being to every ten minutes) was Vieta's 'Canon Mathematicus, seu ad Triangula, cum Adpendicibus,' Lutetiæ, apud Johannem Mettayer, &c., 1579; to which is annexed, with a new title-page, 'Francisci Vietæi universalium Inspectionum ad Canonem Mathematicum liber singularis, Lutetiæ,' &c., as before.

This same book, from the same types, is also found with another title-page, as follows:—'Francisci Vietæi opera mathematica, in quibus tractatur canon mathematicus, seu ad triangula: item Canonion, &c., &c., &c., Londini, apud Franciscum Bouvier, 1589.' This publisher is not mentioned by Ames.

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[*] It would be better if we knew precisely *when* it is good. Not to believe more than half is a very proper caution: but there arises the old difficulty, Which half!

[*] Reinhold taught the higher branches, and Rheticus the lower. It is very illustrative of the neglect into which the prohibition (with other circumstances afterwards noted) caused the writings of Rheticus to fall, that Weidler—himself of the university of Wittemberg, writing and printing his History of Astronomy there, giving minutely the dates of Rheticus's degrees from the *matricula* or register, and stating that from the time when he and Reinhold were colleagues it had always been customary to have two teachers of mathematics—is as ill-informed as any one about the writings of Rheticus, and in particular knows nothing of the publication of 1551, of which we may therefore be pretty sure there was not a copy in the library.

The same book, again from the same types, is in the British Museum with a third title-page, as follows:—'Fran. Vietæi Libellorum Supplicum in Regia magistri, insignis que Mathematici, varia opera mathematica: in quibus tractatur Canon Mathematicus, seu ad triangula; item Canonion, &c., Parisiis, apud Bartholomæum Macæum,' &c., 1609.

That the second and third are really the same book as the first, with a new title-page, we have ascertained by carefully comparing various words which are mis-spelt, and letters and lines which are broken, in all three: also by the fact that the second title-page, 'Francisci Vietæi,' &c., exists, date and all, in the second. In the third, the second title-page is taken out, and Mettayer's address is printed after the first. This book was, from its extreme scarceness, a bibliographical curiosity; we have repeatedly examined five copies, three with the first title-page, one with the second, and one with the third: in two of the first three, some figures which are not found in the third have been stamped in after the printing; and the same stamping is apparent both in the fourth and fifth. The *canon mathematicus* is the first table in which sines and cosines, tangents and cotangents, secants and cosecants, are completely given: they are arranged in the modern form, in which each number entered has a double appellation. But the notation of decimal fractions not being invented, the mode of description is as follows:—to give the sine and cosine of 24° 2′, Vieta states that the hypothenuse being 100,000, the perpendicular and base are 40,727 and 91,330 9; and in a similar way for the others: and here it is remarkable that in the cosines Vieta does use a species of decimal notation, leaving a blank space instead of using a decimal point; for, to an hypothenuse 100,000, the base to an angle of 24° 2′ is what we should now write 91330·9. There is also a large collection of rational-sided right-angled triangles, which form a trigonometrical canon, but not ascending by equal angles. The work concludes with a copious collection of trigonometrical formulæ and various numerical calculations, for mention of which see Hutton's 'History of Trigonometrical Tables,' prefixed to his logarithms, and inserted in his tracts. A short preface by Mettayer, prefixed to the 'Universalium Inspectionum,' &c., states that Vieta found great difficulties in getting tables printed at all, and also that plagiarists had printed and sold something of the kind, but what is not stated. Vieta himself (Schooten, p. 323) calls this book *infeliciter editus*, and hopes that a second edition will be of better authority.

Besides the three title-pages above mentioned, there must have been a fourth; for in the title of that which Delambre examined was the motto *Dura et quiesce*, which certainly was not in either of the three seen by us. The work has well obeyed the direction given: it has lasted in silence, having never been described in catalogues or histories till modern times. Copies seem to have been rare in Germany; neither Weidler, Heilbronner, nor Kastner mentions it. Hutton never saw but his own copy; Montucla (in France!) never saw more than two—one in the royal library, and one sold at the Soubise sale (but it is not in the catalogue of that sale), which the historian would fain have bought, had not a *curieux* bid too high. And this was only by the time Montucla's second edition was written, for by the mention of it made in the first edition it is clear that the author had never seen it. We have examined in London at least eight copies. We have mentioned the complaints which the author had to make against the printers: Montucla states that Vieta bought in as many copies as he could. There are several signs of something odd having taken place in the printing; and the following is worth mention:—To one of the copies we have seen (as well as to one of those in the Museum) is appended one folio sheet, in correction of a mass of errors in one sheet of the collection of formulæ: this sheet is a separate publication, with the date, 1579, and printer's name on it (J. Mettayer).

Vieta imitates Rheticus in his method of heading the tables, but in addition uses the word sine, and calls the table of tangents *fœcunda*, and that of secants *fœcundissima*. He complains that elegant names have not been found, and states that he gets his denominations from certain *Rhapsodi* (as he calls them; it is not often that mathematical tabulators are called rhapsodists), whom he does not name. In a later work, the 'Responsa,' &c. [VIETA, in BIOG. DIV.], published in 1593, he names and objects to the words tangent and secant, which by that time he had seen. And he proposes to call the tangents *prosines* or *amsines*, and the secants *transsinuous* lines.

As to the matter of Vieta's tables, it is worth notice that they must have been made by independent calculation. They do not exhibit the errors in the last tangents and secants which appear in all writings prior to the more correct publication of Rheticus by Pitiscus. On the additions made by Vieta to the theory of trigonometry we have not here to speak: but we may simply say that they made the computation of a trigonometrical canon a much easier thing than it had theretofore been. Delambre is quite right when he observes that the 'Trigonometria *Britannica*' of Briggs is altogether French in all that relates to the non logarithmic part of it. Had he known a little more of Vieta, he could have reinforced his assertion. For Briggs's method of solving equations which Delambre (evidently not understanding it) describes as an obscure mixture of division and extraction of roots, was the slightly amended form of Vieta's numerical exegesis, to which we have referred in INVOLUTION AND EVOLUTION. And as, by Gellibrand's account, we trace the commencement of Briggs's labours to shortly after the time when Vieta first published this exegesis, it is by no means an unlikely conclusion that the power of trisection and quinquisection given by this mode of solving equations first put it into his head to construct the table. [INVOLUTION AND EVOLUTION.]

Purbach and Regiomontanus had seen the advantage of adopting decimal tables, though their use of the radius 600, &c., was a remnant of sexagesimalism. It was reserved for Maurice Bressius to show himself a century behind his time, by publishing in his 'Metrices Astronomicæ Libri Quatuor,' Paris, 1581, folio, sexagesimal tables to every minute of sines, tangents, and secants, or as he calls them, *sines*, *adscripts*, and *hypothenuses*. Thus, the radius being 60°, the sine of 57° 20′ is given as 50° 30′ 34″; and the adscript and hypothenuse as 1 sex. 33° 34′ 46″, and 1 sex. 51° 9′ 44″; 1 sex. meaning 60°. Accustomed as we are to look upon sexagesimal division as sacred to angular and horary measure, we are apt to forget that the time was when other subdivisions were rarely used in Europe.

As yet we do not find the modern names of *tangent* and *secant*. These were introduced in 1583 by a young man of twenty-two years, Thomas Finck, of Flensborg in Denmark (who died in 1656, aged 95), in his 'Geometriæ Rotundi [sic] Liber XIV.,' Basle, 4to. His part in the matter was quite forgotten, and has been recently revived (see Phil. Mag., May, 1845). He introduces the words with expressions which cannot * be interpreted otherwise than as a proposal of his own, to which it must be added that no earlier use of these words has ever been brought forward. The tables of sines, tangents, and secants, so called, which Finck has introduced in his work, are to every minute, and to a radius of 10,000,000. Finck deserves a much higher name than he has got, for the contents of this work alone: there are other writings of his, which we have not seen. He calculated his own secants by a theorem which answers to the formulas

$$\text{Sec}\,\theta = \tan\theta + \tan\left(45^\circ - \frac{\theta}{2}\right).$$

In (1585–6) Clavius published at Rome, in quarto, his edition of Theodosius, to which is appended a treatise on triangles, and a table of sines, tangents, and secants, under those names to a radius of 10,000,000. They were reprinted in the folio collection of his works, Mayence, 1611; and the table of sines only in his 'Astrolabium,' Rome, 1593, 4to. It is clear, on inspection, that these tables are, so far as tangents and secants are concerned, a reprint of those of Finck, in their preliminary theorems, in their arrangement, in their omissions, and in their errors, as well as in the new terms with which they are headed. The name of Finck is suppressed as well as that of Rheticus; both of them were Protestants, and Clavius was a Jesuit, high in favour at Rome. Delambre expresses his astonishment that Clavius, in recapitulating the names of celebrated writers on dialling, should have omitted Sebastian Munster. The fact was that Munster followed Luther. We are not quite certain that a greater than Clavius was altogether exempt from this laughable weakness. When Vieta suppresses the names of his authorities, as above noted, calling them merely *rhapsodists*, we may almost suspect that he wanted to avoid speaking of Rheticus and Reinhold; for he was very intolerant.

In (1591) Philip Lansberg published 'Triangulorum Geometriæ Libri Quatuor,' Leyden, 4to, the first work known to Hutton in which the words *tangent* and *secant* are used; and in 1592 Magini published 'De Planis Triangulis Liber Unicus,' Venice, 4to. Both these contain full tables, taken from Clavius; and Magini is said to have repeated them in his 'Primum Mobile,' Bologna and Venice (1609). Magini, who goes beyond Clavius in historical reference, wilfully suppresses the name of Finck.

We at first thought ourselves unable to give a date to the tables of Stevinus, except within a few years, and conjecturally. That he published his Arithmetic in 1585, and that Snell † collected many of his works in Latin in 1605–8, are the facts which are supposed to mark out the known limits of his career. The tables must have been published after 1593, since Vieta's names for the tangent and secant are mentioned; probably long after, for Vieta's works were of very slow travel. We ourselves believe fully that the Cosmographia, which contains the tables, was never published until it appeared in what is called Snell's collection (in 1608). These tables are to every minute, to a radius of 10,000,000, and they are copies of Finck, Clavius, &c. Recent researches in Belgium have made it appear that Stevinus was

* "Erit AI tangens .... Sic vocare placuit [*i. e.*, nobis] quia .... Damus aliquid .... Regiomontano .... damus etiam aliquid receptæ consuetudini. Verum id non facile damus ut verba ea in usu retineamus quibus elegantiora, breviora, significantiora, veriora habeamus." And again; "Sequitur .... quæ vulgo canon fæcundus, nobis canon tangentium dicitur: et canon hypotenusarum Rhetico, nobis canon secantium vocatur."

† It can be made very obvious that Stevinus *was alive* throughout the whole of the printing of these two volumes (or five volumes bound in two). In the very *last page* of the *last volume* (index excepted), the author excuses himself for not fulfilling certain announcements, because he had not made up his mind about the subjects of them, and the printer could not wait. And this after referring to the places of the several matters in the very volumes which are supposed to be the collection of the editor. Besides, Snell, the reputed editor, was only seventeen years old when the work was published.

born in 1548, and died in 1620, which puts our opinion beyond dispute. The mistake about Snell seems to have originated with Gerard Vossius.

In (1588) Nic. Raymar, Ursus Dithmarsus, published 'Fundamentum Astronomicum, id est nova Doctrina Sinuum,' &c., Strasburg. We cannot make out from the descriptions, whether this work contains tables or not. If Kastner's and Delambre's descriptions be complete, it did not.

Who published the first English trigonometrical table is a point which we have never seen examined: and we must investigate it in the best way we can from rather scanty materials. We cannot find the word *sine* mentioned in the works of Recorde, nor in the English works of either Digges, father or son, nor in those of John Dee; nor indeed in any work written in English before Blundeville, except that of Burroughs presently cited. In the 'Alæ, seu Scalæ Mathematicæ' of Thomas Digges, London, 1573, 4to, trigonometrical processes are required for which allusion is made to Copernicus and Regiomontanus, and the tables of Rheticus are often cited (the ten-minute canon, of 1551). In John Dee's 'Parallacticæ Commentationis Praxeosque Nucleus quidam,' London, 1573, 4to, there are also solutions of triangles, and the tables referred to are those of Regiomontanus with the radius 60,000, before mentioned. But neither of these writers makes the smallest allusion to any tables published in England. We have examined the libraries of more than one diligent collector of English works of the 16th century, without finding anything which at all controverts our decided impression that Blundeville[*] was the real introducer of a complete canon of sines, tangents, and secants.

Blundeville's 'Exercises,' London (1594), 4to (it is said sometimes that 1597 is the date of the first edition, but incorrectly; the fourth is of 1613), were commenced, as he informs us, about seven years before. He alludes to Regiomontanus, Copernicus, and Clavius, from whom he took his tables. And he informs us that Regiomontanus is in folio, and that Clavius is in quarto, and published in 1586, at Rome. We rely much on this in our conclusion that his were the first tables: for to mention the form of a book, or the date of publication, is very rare with the writers of his time; and it is most likely that so precise a person would have noticed any previous work of the same kind in his own country. The tables, being copies of Clavius, have already been described. These 'Exercises' went through seven editions at least: the seventh, now before us, has the tables corrected from Pitiscus, by Robert Hartwell, the editor; it is London, 1636, 4to.

It must be noticed, however, that though Blundeville gave the first English canon complete, a table of sines *only* had been printed four years before. It is at the end of the 'Horologiographia, the art of Dialling,' by Thomas Fale, London, 1593, 4to (reprinted[†] in 1652). The sines are to minutes with a radius of 100,000. This then is the earliest table, but it is of sines only. We have seen that Digges used sines, but he is a Latin writer, and refers to a foreign table. Perhaps the first writer who *used* them in English (but still with foreign tables) is the well-known W. Burroughs, in his 'Discourse on the Variations of the Compasse,' published in (1581). In the preface he apologises for introducing rules "wrought by the doctrine of signes and triangles, which may seem strange in our English-Tongue," and all he gives on tables is in the following passage:—"In these examples I have used the abridged table of 100,000 the whole sine, which though it give some ease in the working, yet it is not so exact as that of 10,000,000 of *Erasmus Reinholdus.* Unto the which, with his *Canon fæcundus*, answerable to the same, if the third *Canon* of the *Hypthenusæs* were annexed, wee should have an entire Table for the Doctrine of Triangles, that might worthily bee called *The Table of Tables.* Which thing, though *Georgius Joachimus Rheticus* have well begunne, and framed it orderly, from ten Minutes to ten: yet is it left very rawly, for such as desire the exact truth of things. I have therefore for mine owne ease and use, Calculated the complement of this Table, and almoste ended it, for the whole Quadrant, from minute to minute: which if in the mean time before I have finished, I shall not finde it extant by any other, I will publish it for the commoditie of all such as shall have occasion to use the same for navigation and cosmographie." But this table was never published, and accordingly the editor of the edition of 1614 refers the reader to Ralph Handson's translation of Pitiscus, and the very tables of that work are annexed to the end of some copies at least of the edition of 1614. They are tables to every minute, and to a radius of 100,000. The table is semi-quadrantal, and the complementals are joined in contiguous columns, without any heading by which further than 45° could be guessed at. We cannot describe the first edition of Handson's work, having only seen the second, which is London, 1630, 4to; at least the *tables* are so dated, though the *work* has no date. (Wilson, in the preface to his Navigation, says the first was in 1614.) In 1609, John Speidel, afterwards well known in the history of logarithms, began his career by publishing, in quarto, 'Certaine verie necessarie and profitable Tables; namely, A Table of Sines, Tangents, and Secants, &c.' This tract of sixteen pages contains a canon to every ten minutes, and to a radius 1000, with some tables subsidiary to astronomy.

In 1610, Arthur Hopton published 'Baculum Geodæticum sive Viaticum, or the Geodæticall Staffe,' London, 4to. The seventh book of this is called 'Trigonometria, containing Longimetria, and Altimetria, performed by Synnicall supputation, with a Canon for the Dimension of tryangles.' The canon (from Pitiscus) is complete for every five minutes and to a radius of 100,000. Peculiar to this table is a heading by which the sine, tangent, secant of the complement, or defect from 90°, are also made to belong to the excess above 90°; thus at 10° the sine, tangent, and secant of 80° are made to be those of 100°.

The history of the rest of the works of Rheticus was, till lately, very inaccurately told, and there is still some confusion about it. After Rheticus had published his ten-minute canon, already noticed, in 1551, he was occupied till his death in 1576, in what is, beyond a doubt, the most laborious work of calculation that any one man ever undertook: a complete trigonometrical canon to every ten seconds, and to ten places of decimals, sines to every ten seconds, and to fifteen decimals, with the first and last degree to every second, and tangents and secants to every minute, and to fifteen decimals. It is to be remembered that he wanted the abbreviations which might have been introduced, if he had known what Vieta had done. At his death, he had finished this work, within a mere trifle: what little remained to do, was done by his pupil Valentine Otho, and part of it was published at Neustadt[*] in the Palatinate, 1596, in folio (sometimes bound in two volumes, from its thickness). The title of the book, which was published at the expense of the Emperor Maximilian, is 'Opus Palatinum de Triangulis a Georgio Joachimo Rhetico cœptum: L. Valentinus Otho Principis Palatina Frederici IV. Electoris Mathematicus consummavit.' The contents are (after prefaces) three books *de Fabrica Canonis*, on the construction of the Canon, by Rheticus; one book on plane triangles, and four books on *right-angled* spherical triangles, by the same; five books on oblique-angled spherical triangles by the editor, Otho; three subsidiary astronomical tables called *meteoroscopia;* the great table, in 540 folio pages, giving, under the titles already described, the sines, tangents, and secants, for every ten seconds, with a radius of 10,000,000,000, or, as we should now say, to ten places of decimals; a list of errata; and lastly, a second table of cotangents and cosecants for the first half of the quadrant, to every ten seconds as before, and to a radius of 10,000,000. The appearance of the last table is merely the editor's want of judgment; it is clearly nothing but a previous attempt, made before the larger plan was resolved on, and is much less accurate than the great table to ten places.

Within a short time after the 'Opus Palatinum' was published, it was found (by whom or how we are not told) that the tangents and secants towards the end of the quadrant became more and more erroneous, and at the extreme end were very erroneous indeed. All persons who know anything of trigonometry are aware that, to calculate the tangent or secant of an angle near to 90° true to any number of decimal places requires that the cosine should be calculated to a greater number of places. Rheticus seems to have foreseen this, and to have provided sines true to a larger number of places than those which were published. When the defect was discovered, the advisers of the Elector Palatine, Frederick IV., to whom the work was dedicated by Otho, caused him to intrust the superintendence of the corrections to Bartholomew Pitiscus of Grünenberg, in Silesia, who had been his own teacher, and who was still in his service as chaplain: we suppose this means that Pitiscus himself was the adviser. Pitiscus applied to Otho, then an old man, for the larger tables of sines which Rheticus was known to have calculated: Otho was never able to find them; but at his death they were found among his papers. Pitiscus accordingly made *two* publications; but so confused are the statements respecting them, that some of our readers may almost doubt the fact. These two publications were as follows: 1. He corrected all that part of the great table of the 'Opus Palatinum' in which the tangents and secants are sensibly erroneous, being the first 86 pages. These he reprinted, and joined his reprint to the 540—86, or 454 remaining pages of the great table. He then cut away all the *Fabrica Canonis*, the books on triangles, the *Meteoroscopia*, and the small table of cotangents, &c., and added to his own 86 pages and Otho's 454 a short description, or *commonefactio*, as he calls it. This of course gives a thin folio. But we collect from Delambre's account of Prony's copy, that besides this, there were such things as complete copies of the 'Opus Palatinum,' with the 86 correct pages substituted for the incorrect ones. And we presume that to these the separate title of the *commonefactio* was not appended, being printed only for the separated table. For Prony, Delambre, and all the rest of the French savans (to whom the subject was particularly interesting, on account of its connection with the 'Tables du Cadastre,' then preparing) missed the date of the correction, which nevertheless appears on the separate title-page of the *commone-*

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[*] This is the same as the Blundeville who wrote on Horsemanship. In 1846, a patent for a horseshoe was upset in Chancery, upon proof that Blundeville had described it before 1600.

[†] That is to say, furnished with a new title-page: beyond a doubt the type is of the previous century. This, we find, was not an uncommon practice in the middle of the 17th century, in England. We suppose that the civil troubles, which operated against the production of all but theology or politics, threw the booksellers back on their old stocks, which they then replaced with new title-pages, defacing the 17th century with some of the worst specimens of the irregular black letter of the 16th.

[*] Weidler, copied by Montucla, gives Heidelberg, 1594; and Lalande reconciles them with fact by taking *Neostadium* to be Latin for Heidelberg! The Neustadt here mentioned is now part of Bavaria, lat. 49°+, long. 11°−.

factio. The person who is used to accurate descriptions of books might possibly, without this warning, throw away the thin folio we are speaking of, under the idea that it could not be in any sense an edition of the Opus Palatinum: which in fact it is not, though it is an edition of all that was corrected. The 86 pages of reprint are easily distinguishable by the inferiority of paper and type.* The title-page of the thin book is a sort of fly-title, without date, &c., on the first page as follows:—'Georgii Joachimi Rhetici magnus canon doctrinæ triangulorum ad decades secundorum scrupulorum, et ad partes 1 0000 00000. Recens emendatus a Bartholomæo Pitisco Silesio. . . . Addita est brevis commonefactio de fabrica et usu hujus Canonis. . . . . Canon hic, una cum brevi commonefactione . . . . . etiam separatim ab opere Palatino venditur. In bibliopoleio Harnischiano.' And the *commonefactio* has a title-page of its own, as follows: 'Bartholomæi Pitisci Grunbergensis Silesii Brevis et Perspicua commonefactio de fabrica et usu magni canonis doctrinæ triangulorum Georgii Joachimi Rhetici. Neostadii Typis Nicolai Schrammii MDCVII.' It thus appears that the date is 1607, which no one has yet noted, except Kastner, copying an older description, apparently without any distinct separate knowledge of what he was describing. 2. Pitiscus published, Frankfort, 1613 (misprinted on two of the titles 1513, by omission of a C), folio, the tables of Rheticus by which himself was enabled to make the preceding corrections, under a long descriptive title beginning with 'Thesaurus Mathematicus.'† The contents, described in modern language, are:—sines to every ten seconds and to fifteen decimals, with first, second, third, and sometimes more differences; those of the first and last degrees, also to fifteen places, and to every second: the fundamental sines, from which the rest were calculated, to twenty places: the sines of every 10th, 30th, and 50th second in the first 35 minutes to 22 places (this last table was done by Pitiscus himself). Pitiscus died in July, 1613, very shortly after the publication of the Thesaurus.

When we come to reflect, we find that the tables of Rheticus did not make such an epoch in the history of these things as might have been expected. The ten-minute canon, 1551, which we have described, and of which the memory was almost lost, introduced the secants, completed the system, and suggested to Vieta both the extension and its form. Had Rheticus published his own large table before his death, in 1576, it might have been otherwise: but deferred as this publication was, partly till 1596, seventeen years after Vieta's Canon had appeared, and partly till 1613, the year before the publication of logarithms it turned out that the impulse had already been given from other quarters. The next great tables of sines which were produced were the work of Briggs, who was, as we have seen, exclusively the follower of Vieta in this part of the matter. The labours of Rheticus became little more than a tradition, though Vlacq used the last half of his quadrant in the construction of logarithmic sines. Vossius, 1650, knew nothing definite of the tables except the Thesaurus, and that only in time to insert it in the additions to his work. Sherburne, 1675, has not a word of tables. Briggs hardly mentions Rheticus; his biographers not at all. The Jesuit Blancanus omits him as a condemned writer; and it is to be noticed that he was, as to this matter, worse off than Copernicus himself; for he was *damnatus auctor*, Copernicus only *damnati libri auctor*: and the absolute prohibition against all his writings must have tended to the oblivion into which his name fell. Weidler, 1741, writing in the University of Wittemberg, in which Rheticus taught, had not seen the Opus Palatinum, and knew nothing of what Pitiscus had done. In the Berlin Memoirs for 1786, John Bernoulli (the younger) revived the knowledge of the 'Opus Palatinum' and the 'Thesaurus;' and Lalande had previously come at some statement to the effect that Pitiscus had once received instructions to correct the former. But Bernoulli knew nothing of these corrections, and nothing was known until chance threw a copy of the corrected Opus Palatinum into the hands of Prony, who described it in a paper printed in the fifth volume of the Memoirs of the Institute, 1804. Delambre gave an accurate account at the beginning of the second volume of the 'Histoire de l'Astronomie Moderne.' Montucla had given nothing but mistakes. Hutton knew as much as Bernoulli. Kastner (1796, who would have got much more credit if he had given a proper name to his valuable work of bibliography, instead of calling it a history of mathematics) has a detailed account of all the matter, except the corrections of the Opus Palatinum, on which he could only quote from a periodical of 1789.

In (1599) Pitiscus published his own work on Trigonometry, with tables, generally to seven places, and having intervals which may be described, as presently noted, by 0 (1") 1' (2") 10' (10") 1° (1') 45°. The edition of 1608, now before us, has of course the corrected tangents and secants. It was reprinted again in (1612), and Dechales mentions a reprint, by Henrion, in (1623).

Pitiscus will always be remarkable as the priest who wished that all his brethren were mathematicians,* to make them manageable and benevolent.

Among the non-logarithmic tables, which were published after the invention of Napier turned all the calculators another way, was that of Schooten, 'Tabulæ Sinuum,' &c., Amsterdam, 1627, a complete canon to seven places, in a pocket volume with pages of two inches by four. It is often said to contain no error; but we believe the author's own assertion in the preface is the source of this opinion: Hutton found many errors in the last figures. There were two *principes* editions, one with explanations in Latin, the other in Dutch. Lipenius says this was reprinted in (1638?) and we know there is an edition of (1672) at Rouen, and of 1683 at Brussels. Editions are mentioned of (1640) and (1664), and also a Spanish edition, Brussels (1683), and of 1683 at Amsterdam, from different type. Joh. Meyer's tables, Strasburg (1619), contain sines, tangents and secants, squares, and cubes. Those of Adrian Metius (1633) give a complete canon, to minutes, to seven decimals. In (1627) Snell published his 'Doctrina triangulorum canonica,' Leyden, containing a complete canon to every minute, and to seven places. Cruger's 'Synopsis Trigonometriæ,' Danzig (1612), gave a five-decimal canon to minutes. Albert Girard's 'Tables des sinus,' &c., Hague 1627, are to five decimals; there was a Dutch reprint in (1629). Adrian Romanus gave tables (Delambre, 'Astr. Mod.,' vol. ii. p. 35) in (1609); they were taken from Clavius. The greater part of the contents of this paragraph are taken from different sources, and not from the books themselves. We might mention some anonymous tables from various catalogues, but anonymous works of this kind are so rare that we always suspect them. One, however, now before us, deserves mention. It is a thin quarto, Wurtzburg (Herbipolis), 1625, announced as intended for the students of the University. It contains a semi-quadrantal table of sines (only), and is entitled 'Canon sinuum ad decempedam accomodatus.' The table is to a radius of 10,000, but the four places of each sine are severally called radii, pedes, digiti, grana; and are so headed in every column. The degree is divided into 12 parts, each of which is called a *minute.*

Alsted's 'Encyclopædia,' 1649, the earliest work which has bulk enough to be compared with modern works of the same name, gives nothing more than a canon to degrees and seven decimals, with another to ten minutes and five decimals. The name only of logarithms is mentioned, and an insufficient definition given.

§ 6. *Tables of Logarithms.*—Before we enter on this subject we shall give a hint which may be worth the attention of future compilers, though in joining together two articles of older date than the additions we have not been able to take advantage of it to any great extent. Systems of tables may be arranged and spoken of either by their *sources* or by their *forms.* Thus in thinking of old books of logarithms we may have to ask whether they came from Vlacq or direct from Briggs; we also want to know the number of figures, the arrangement, &c. The tables of logarithms might with some trouble be divided into sets, those in each set being lineal descendants of their predecessors.

Our mention of different works will be found, as to length and minuteness, much out of proportion to their celebrity, in many cases: this cannot be avoided when we have information to give which is not commonly found.

1614. Napier, 'Mirifici Logarithmorum Canonis Descriptio, Ejusque usus, in utraque Trigonometria, ut etiam in omni Logistica Mathematica, Amplissimi, Facillimi, et expeditissimi explicatio. Authore ac Inventore, Ioanne Nepero, Barone Merchistonii, &c. Scoto. Edinburgi, Ex officinâ Andreæ Hart, Bibliopôlæ, CIↃ.DC.XIV.' 4to. Sines and Naperian logarithms of sines and tangents, to every minute and seven decimals.

It must be specially noted that the logarithms which Napier himself published are not precisely those which are now called Naperian; that is, they are not the simple logarithms to the base $\epsilon = 2{\cdot}7182818\ldots$ As the sines increase, his logarithms decrease. As he uses no decimal point, both his sines and logarithms are integers, the former to a radius of 10 millions. And if N be a sine and L the logarithm of it, as they stand in Napier, the equation connecting them is

$$N = 10{,}000{,}000\,\epsilon^{-\frac{L}{10{,}000{,}000}}$$

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* The corrected copies of the work, thick or thin, may be distinguished from the uncorrected ones in a moment, as follows: Look at the bottom of page 7, at the running titles of the columns. The uncorrected copy will have, as it ought to have,

Basis Differentia Hypothenusa.

But the *corrected* copy (*quis custodiet ipsos custodes?*) will have, as it ought *not* to have,

Hypothenusa Differentia Basis.

† The copies of the two works, the 'Opus Palatinum,' and the 'Thesaurus,' which belonged to Delambre, were bought at the sale of his books by Mr. Babbage. The copy of the 'Thesaurus' is curious: it once belonged to De Thou, and was bequeathed to Delambre by Lalande. It sold at the sale for 216 francs; the 'Opus Palatinum' for 60 francs. Mr. Babbage has also a copy of the corrected table (the thin volume). He informed us that, in 1828, Reuss, the librarian at Göttingen, and the indefatigable editor of the 'Repertorium Commentationum,' &c., the most complete digest of scientific transactions which exists, was altogether ignorant of the existence of any corrections of the Opus Palatinum. This is a truly singular instance of the slowness with which bibliographical information spreads.

* In his preface he says, "Mansuetudo autem, bone Deus, quantum et quam rarum est Theologorum ornamentum! Et quam optandum esset hoc seculo, omnes Theologos esse mathematicos, hoc est, homines tractabiles et mansuetos." Perhaps the union of the characters of divine and mathematician gives a peculiar right to speak well of the latter; for Barrow says, "Tenerrimæ frontis et stomachi robustissimi, aut si mavis, pudentissimum tædiique patientissimum genus hominum sunt mathematici." We accept the *si mavis*, for there is no saying how the moderns might translate the first epithets.

Delambre proposes to call them *Naperian* logarithms, and to restrict the term *hyperbolic* to the *modern Naperian* or ε logarithms: but custom has refused.

The reader may have some curiosity to see a specimen of the *tabula princeps*: we therefore subjoin three lines from the page having Gr. 37 at the top and Gr. 52 at the bottom. The form is semiquadrantal, and the *differentia* is the logarithm of the tangent.

		+	−			
37 min.	Sinus.	Logarithmi.	Differentiæ.	Logarithmi.	Sinus.	
0	6018150	5078050	2829544	2248506	7986355	60
1	6020473	5074191	2823492	2250699	7984604	59
2	6022796	5070334	2817441	2252893	7982852	58

This work of Napier was reprinted by Baron Maseres, in vol. vi. of the 'Scriptores Logarithmici.'

(1616.) Reprint of the above, by Edward Wright, to one figure less, with Napier's explanation translated into English, and preface by Briggs, London.

(1617.) Briggs, 'Logarithmorum Chilias Prima,' London. This is the first publication of logarithms on Briggs's system.

(1618.) Benjamin Ursinus, 'Cursus Mathematicus,' Cologne, contains Napier's Logarithms. For his 'Magnus Canon,' see 1624.

(1619.) John Speidell, 'New Logarithms.' A new arrangement of Napier's, but giving sines, tangents, and secants, with numbers also to 1000. These 'New Logarithmes' are the first *modern Naperian*, or *hyperbolic* logarithms. The second edition was in 1620, not 1627, as we stated (from others) before we had seen it. The reason of the mistake is that the 'Briefe Treatise of Sphæricall Triangles,' which is frequently prefixed, has 1627 on its title-page.

Taking decimals it stands thus:—If $m : n$ be the sine of an angle, and if λ represent the logarithm to the base ϵ, the *figures* of the Naperian logarithm are found in

$$\lambda n - \lambda m.$$

Thus, the sine of 19° 38′ is ·336, very nearly. And we have

$$\begin{aligned} \lambda\ 1000 &= 6{\cdot}9077552\ldots \\ \lambda\ 336 &= 5{\cdot}8171111\ldots \\ \hline & \ 1{\cdot}0906441 \end{aligned}$$

Napier has 10906448.

The figures of Speidell's logarithmic sine are found in

$$10 + \lambda m - \lambda n$$

thus for 19° 38′ he has 890936. But he leaves the 10 out of all the secants and the last half of the tangents. His logarithms of numbers, 0 (1) 1000, are modern hyperbolic to six decimals, as we should now say, but without the decimal point; thus at 770 he has 6646388 not 6.646388. To each logarithm he gives its difference, its arithmetical complement, and the halves of all three. Also an additional column which shows that he means to use his table in calculation by feet, inches, and quarters. Thus the number 775 has 16.1.3 opposite to it, there being 775 quarter inches in 16 feet 1 inch 3 quarters. At the bottom of each page he puts the logarithm of 100 and of 1000, for help in decimal fractions.

Speidell, as we have seen, first published in (1619); Baron Maseres reprinted from the "tenth impression," dated (1628); there was an edition in (1627); Hutton mentions the seventh, dated (1624); we have the fifth, dated 1623, and the sixth, dated 1624; the Royal Society has one of 1623; Murhard gives the third impression, of (1621), and we have the second, dated 1620. In his "briefe treatise" above mentioned, Speidell mentions, and naturally complains of, those[*] who had printed his work without an atom of alteration, and yet dispraised or undervalued it in their prefaces for want of alterations which themselves either could not or would not make. This he attributes to his not having been at Oxford or Cambridge.[†] Having kept our eye on this work until we have obtained four copies of it, though the British Museum[‡] does not possess one, without ever finding the smallest trace of any reproduction by another hand, we permit ourselves to doubt Speidell's assertion about the reprints: and the more readily after finding out the reasons for suspecting him of unfairness of which we shall presently speak.

Whether for his own reason or not, Speidell's name was very little known.[*] The Continental writers rarely mention him; Wallis knew nothing of him; and even his own son, Euclid Speidell, when he published his 'Logarithmotechnia,' in 1688, had no accurate information on his father's writings; for he says, "I do find my father printed several sorts of logarithms, but at last concluded that the decimal or Briggs's logarithms were the best sort for a standard logarithm, and did also print the same several ways." This must have been merely a mistaken tradition, arising from Speidell's not having printed the same logarithms as Napier: we may safely say he did not print any decimal logarithms. In addition to this testimony as to the rapid spread of logarithms in England which Speidell's circulation gives, we may state that their advantages were immediately seen by the practical mathematicians. Aaron Rathborne, in his 'Surveyor,' London, 1616, recommends the use of the "tables and more than admirable invention of logarithmes by that divine and noble writer the Lord Marchiston, whoes name and honour will never out."

It is to be noticed that two different tables of common logarithms accompanied Speidell's sines, &c. Our second, fifth, and one of two copies of the sixth, have, through 0 (1) 1000, the logarithm and its complement with the common difference between them, and, by the side of them, the semi-logarithm and semi-complement, with *their* common difference between them. But our other copy of the sixth impression has nothing but plain number and logarithm, without even the differences. And the larger table has, up to 960, an argument in shillings, pence, and farthings.

Thus far we had got in the revision of our former article, when we took it into our heads to compare the four copies before us, and, excepting only the new table of common logarithms in one of the *sixth* copies, we found them to be all from the same type, even to the very title-pages. It is true that one has 'The 2. Inpression. 1620,' and another 'The 6. Inpression. 1624,' &c.; but as much as 'The Inpression. 162 ' is from the same type in all. We cannot be deceived here, though those who are not used to such comparisons may think it possible. The inferior printing of that period abounds in badly formed, ill ranged, and blurred letters: and every instance of malformation is common to all our three cases. Hyphens, in particular, are very good tests: and one in "Ho-nourable" which happens to slant upwards in all three, and another in "Play-House" which happens to slant downwards, are hardly possible coincidences. Either the type was kept standing, and each year's sale was called an impression, or the title-page was several times fraudulently set forward in date after a number of copies had been taken off. There is no printer's name; and that the type should have been allowed to stand for many years is very unlikely, though we must see that the occurrence of an inferior table of common logarithms in the late editions is in favour of the supposition. It seems to favour the hypothesis that the forms of some of the last pages got broken up by accident, and that the inferior table was set up to replace them.

1619. Napier. 'Mirifici Logarithmorum Canonis Constructio,' Edinburgh, edited by Napier's son.

1620. Reprint of Napier, both the 'Descriptio' and the 'Constructio,' at Lyons, by Bartholomew Vincent, bookseller.

(1620). Gunter, 'Canon of Triangles,' first trigonometrical canon with Briggs's 'Logarithms.' We have not seen the first edition of this canon, which is semi-quadrantal, 0 (1′) 45° to seven decimals, and 0 (1) 1000 to eight. It was certainly first published in 1620, alone; and Wingate, in 1624, states it to be of Gunter's own calculation, and acknowledges it as the source of his own reprint. A year or two afterwards, the work on the cross-staff was published, to which this canon was attached: and in future editions the two always went together. The second edition of both was in 1636; the fourth (edited by Henry Bond, who perhaps edited the third, of which we know nothing) in (1662); the logarithms of numbers being 0 (1) 10,000 to seven decimals. Gunter is entitled to rank as one of the primary calculators of logarithms, with Napier, Briggs, John Speidell, and Vlacq.

(1620). J. B. [Justus Byrgius], 'Arithmetische und Geometrische progresse Tabulen,' Prague. This is the title given by Montucla, and the history of the book is as follows:—Kepler had stated that Byrge had invented the very same logarithms as Napier many years before the latter published anything on the subject. And Bramer, author of a German work on perspective, Cassel (1630), says that his brother-in-law and teacher, Justus Byrgius, had, twenty years before that time, made a table of progressions with differences of 10, calculated to nine figures, which he had published without text at Prague in 1620. This announcement obtained no notice, until Kästner informed Montucla

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[*] To them he speaks as follows, in the introduction:—

> "To the M. C. Z.
> If that thou canst amend it,
> So shall the Arte increase:
> If thou canst not: commend it,
> Else, preethee hould thy peace."

[†] "Yet to satisfie in part the learned, that I can giue a reason for what I doe, I will set downe the making of these 2. last Theorems, whereby they may (if so they please) suppose I can doe as much for the rest, and whether some of them doe or no, I passe not greatly, for that they are sorry I can doe so well, not hauing seene one of the Vniuersities" (p. 27).

[‡] The British Museum is well supplied with mathematical works of the period: and the deficiency illustrates what we shall say on the decadence of J. Speidell and his works. It is very much to be regretted that the Museum did not purchase Dr. Hutton's library. The matter was in discussion, and almost in negotiation; but things were prevented from going further by Sir Joseph Banks. Hutton distinctly declared, both at the time of the sale and after, that his "old implacable enemy" had prevented the Museum from making the purchase, and that such was the frequent opinion of those who thought about such things. (Bruce, 'Life of Hutton,' Newcastle, 1823). Thus the finest set of mathematical tables ever collected in England was dispersed.

[*] There is not now a copy of any edition in the British Museum. Hutton happens to say that there is in the seventh impression (being the one he had before him) a table of logarithms of numbers. In the 'Encycl. Brit.' this is translated into an assertion that the logarithms of numbers were not added until the seventh impression.

(how, Montucla does not state; probably by private communication, or perhaps Montucla ought to have cited the 'Fortsetzung der Rechenkunst,' 1783) that this passage of Bramer had led him to look at some old tables which he had bought, and which had lain by neglected. And in these old tables he says he found the above work of Byrgius. This occurs in the second edition of Montucla's History, vol. ii. p. 10; see also Kästner's History, vol. ii. p. 375, and vol. iii. p. 14; and Delambre, 'Hist. de l'Ast. Mod.,' vol. i. pp. 560-566. It will be noticed that Byrgius did not publish till six years after Napier; so that in all probability Napier is first in point of invention as well as publication. Byrgius's system begins with 0 as a logarithm and 10^9 as a number; for every increase of the logarithm by 10, the number is multiplied by 1·0001; so that 10m has for its number $10^9\,(1{\cdot}0001)^{m-1}$. This is undoubtedly a rude table of logarithms, or rather of numbers to logarithms; and since Byrgius carried it up to 230270, the number to which is 999999999, he certainly secured the main advantages of logarithmic calculation.

Delambre, who has in general treated Napier with fairness, has in one instance formed a conclusion on premises so strange, that we hardly remember the like in any historian. ('Astr. Mod.,' i. 287-291.) Ursus Dithmarsus, the pupil of Byrgius, in his work of 1588 already mentioned, hints at some method by which he can calculate sines *even in numbers*, and *arithmetically*; and afterwards he talks of doing this in *common* numbers, by inscription, and in *logistic* numbers, by section of the angle. What he means Delambre cannot understand, neither, we should suppose, can any one else: but, seeing that he is a pupil of Byrgius, who afterwards made an antilogarithmic table, Delambre interprets him as possibly conveying the ideas of Byrgius to Napier. That is to say, certain unintelligible professions of Ursus, who does not even attribute them to Byrgius, and in which Delambre himself, with all his knowledge of logarithms, can neither see logarithms nor anything else, may have given the first idea of logarithms to Napier, or may furnish presumption that Byrgius gave that idea in some other way. One would really almost suppose that Delambre had been misled by the antithesis of *common* and *logistic* numbers, the usual terms of the day for integers and fractions. Thus, Kepler begins the Rudolphin tables by a chapter on the *logistics* he means to use, and warns the *logista* that he will express the distances of the planets by dividing that of the earth and sun into 100,000 parts.

The following is a summary of the ground of presumption that Napier's system was well advanced, in thought at least, if not in actual calculation, before 1588. Kepler testifies that Napier gave Tycho Brahé strong hints of what was coming in 1594. Now in 1593 Napier published the first edition of his interpretation of the Apocalypse; and there is no reason to doubt his declaration that he considered this as the main business of his life, and mathematics as only secondary. This heavy work shows what was his main employment in the years preceding 1594, in which year his system was well advanced: which we take to make probable, all things put together, that it was well advanced at least four or five years earlier. Napier returned from travel and settled down to study in 1571, and probably he soon began his researches. It is to be noticed that his system of logarithms did not stand alone. He informs us that he tried many plans to facilitate calculation, some of which might perhaps be published: this he says in the preface to his canon of logarithms. Accordingly, in 1617, the 'Rabdologia' appeared [NAPIER'S BONES]; and this was only one of three plans, of which the others are but named. Napier was not in haste to publish. His son informs us that the second tract, the 'Constructio,' was written years before the name *logarithm* was invented; and this description must have followed the actual calculation of much, if not all, of the canon.

1624. Briggs, 'Arithmetica Logarithmica,' London. Logarithms (decimal) to fifteen places, from 0 to 20,000, and from 90,000 to 100,000, with interscript differences. After his death, in 1631, a reprint was, it is said, made by one George Miller; the Latin title and explanatory parts were replaced by English ones; 'Logarithmicall Arithmetike,' &c. We must doubt the reprint of the tables, and think that they were Briggs's own tables, with an English explanation prefixed in place of the Latin one. Wilson (in his History of Navigation, prefixed to the third edition of Robertson) says that some copies of Vlacq, of 1628, were purchased by our booksellers, and published at London with an English explanation premised, dated 1631. Mr. Babbage (to whose large and rare collection of tables we were much indebted in the original article) has one of these copies; and the English explanation and title is the same as that which was in the same year attached to the asserted reprint of Briggs. We have no doubt that Briggs and Vlacq were served exactly in the same manner. Some copies of Briggs have, after the 'Finis,' another chiliad of logarithms, headed 'Chilias centesima prima,' and arranged like the preceding ones; also, a page of square roots, to eleven decimals, from 101 to 200. In some copies the page of errata follows the additions.

1624. Benjamin Ursinus, 'Magnus Canon Triangulorum Logarithmicus ex voto et consilio Illustr. Neperi p.m. novissimo,' Cologne (at the end, Berlin), 4to. This is an extension of the *original* Naperian logarithms to eight figures, and to every ten seconds: the last places are much more correct. The arrangement is entirely that of Napier, with the addition of the tabular differences, headed *differ.* or D., the heading of the logarithmic tangents being *different.* (contraction of *differentiæ*). There is no preface; but the 'Trigonometria cum magno Logarithmorum canone,' published in the next year at Cologne by Ursinus, contains the necessary explanations. It is bound up with the canon in the copy we have seen; and probably the canon was not issued without it.

(1624.) John Kepler, 'Chilias Logarithmorum,' Marpurg, and (1625) 'Supplementum . . . continens Præcepta de eorum Usu.' These were reprinted by Maseres, in vol. i. of the 'Scriptores Logarithmici.' See a very full account of them also in the first volume of Delambre's History of Modern Astronomy. The logarithms are strictly *Naperian*, 0(1)1000, but four ciphers are put to the end of each number, to make the radius ten millions. There are five columns, of which this is a specimen:—

44° 30′ 26″ | 7010000 | $16^h\ 49^m\ 26^s$ | 3552474 | 42° 4′

The number here is 701, and the sine being 7010000, the angle is 44° 30′ 26″. The logarithm is 3552474. And if 1000 represent 24^h, then 701 represents $16^h\ 49^m\ 26^s$; while if 1000 represent 60°, 701 represents 42° 4′. There are also interscript differences. And thus Kepler originated the species of table now called *logistic*.

1625. Wingate, 'Arithmetique Logarithmique,' Paris (reprinted at Gouda, in 1628, according to Murhard). Wingate was an Englishman who first carried Briggs's logarithms into France. The work was reprinted in England, in the same year. Dodson, Hutton, Ward, &c., say the year of the French publication was 1624; but Lalande and Delambre knew of none previous to 1626, and a copy of the last date which we have examined bears no mark of being a second edition, and refers to nothing as published before, except a tract on the rule of proportion (Gunter's Scale). The logarithms are from Gunter.

But we have found a copy dated 1625, and we are satisfied, from the date of the "privilège" and other things, that this was the first edition. That date is November 4, 1624, and the printing is stated as having been finished April 4, 1625. This edition and that of 1626 are from the same types, except in their title-pages and a page or two of the postfixed explanations. The latter has also a further appendix of differences and some points of explanation. It has also additional (perhaps, for the same thing may have been torn out of our copy of 1625) a folding sheet of mean proportionals between 10 and 1. The contents are,—seven-decimal logarithms of numbers 0(1)1000 with interscript differences; and 0(1′)45° logarithms of sines and tangents, with the complemental parts on opposite pages. These logarithms are from Gunter. This is the introduction of Briggs's logarithms into France; that of Napier's was made, as noted, by B. Vincent.

(1626.) Henrion's 'Logarithms,' Paris. (Dodson, followed by Hutton.) Lalande knew nothing of this work, nor Delambre. All we can learn is from Dechales, who states that Henrion wrote on the proportional compasses in (1623), reprinted in (1681), and on the rule of proportion (which we take to be Gunter's scale) in (1626); and that this last work contains logarithms of numbers up to 2000.

1626. 'Tables des Logarithmes pour les nombres d'un à 10000, composées par Henry Brigge. A. Goude. Par Pierre Rammaseyn.' The negligence of a bookbinder enables us to clear up some confusion, in rather a singular manner. Sherwin states that he examined his table by one of Vlacq's, in large[*] octavo, printed at Gouda in 1626, of which table we find no other mention. The table before us corresponds in every respect, except that there is no author's name; but no one except Vlacq can be mentioned, who was in the least likely to have printed logarithms at *Gouda* in or about 1626. At one time we thought that *this* table was the original of the long series of small tables called after Vlacq; but this was a mistake (see 1625, Gellibrand), and the mistake was partly due to the following circumstances. This table, Gouda, 1626, having the title, when not cut away, above described, and which we have also seen with a Dutch title and preface, is the table which is always bound up at the end of 'Sciographia, or art of Shadowes . . . . by T. W[ells], Esq.,' London, 1635, large octavo. It has a preface by Gellibrand, who was thus accessory to the introduction of *one* small table by Vlacq in the very year in which he (Gellibrand) published *another* small table, the reprints of which were destined to be called by Vlacq's name. That the book was intended to have these logarithms bound at the end is evident from every page of it. Now the fact stands as follows:—A sufficient number of copies of the logarithms having been procured from abroad, the binder was directed to cancel the title-page of the logarithms, and to append them to the work. Accordingly, most copies have no title to the logarithms, which look quite like part of the work. But in some copies the binder has not cancelled as required; we have obtained two (since our first article was written), and there is another in the library of the Royal Society. But in all three copies the title of the logarithms is cut half way up with knife or scissors, as a direction to the binder to cancel it. One of our copies has this Dutch title-page to the table, 'Henrici Briggii Tafel van Logarithmi voor de Ghetallen van een tot 10000. Ter Goude . . . 1626.' And the work (though the same impression as before) has a different title-page and date—namely, 'The Compleat Art of Dyalling . . ., by T. Wells of Deptfort, Esq.,' London, 1637.

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[*] The work we shall describe would not now be called large octavo; but may have been so in Sherwin's eyes. The octavo sizes (and indeed all the sizes) varied as much as they do in our own day, when between post, demy, royal, &c., we hardly know what is and what is not octavo.

This table contains logarithms of numbers 0 (1) 10,000, to ten decimals, and a complete canon (of logarithms only, and of semiquadrantal form) to every minute and to seven decimals. But the terms cosine, cotangent, cosecant, are not yet introduced.

(162[illegible].) John Maire 'Canon Mesotetologisticus,' &c., Leyden. Such a work is mentioned by Murhard from Scheibel. It contained sines of minutes, to 7 decimals, in Napierian logarithms; with differences to ten seconds.

1627. John Kepler, 'Tabulæ Rudolphinæ,' folio. Among the tables in this celebrated work are the following: First, a variation of the *logistic* table. Next, a table of logarithms, opposite to which are the angles of which they are the *Naperian* logarithms of sines, and adapted to the two ascending arithmetical series 5", 10", ... 60', and 2^m, 4^m, ... 24^h, and to the reciprocal, or harmonic series, 720, 360, 240, ... 1. This table, from its number of terms, he calls a *heptacosias* of *logistic* logarithms: we shall see that Batsch extended the first term; and we note that Kepler here introduced the other. Secondly, a reprint of Napier's own table of sines and (now called) cosines, to two figures less than in Napier. Kepler calls the logarithms of cosines *antilogarithms*, and abandons his right to the word at the same time. For in Napier's semiquadrantal form, the cosines do stand *over against* the sines: but in Kepler's quadrantal form they do not. Napier does not use any distinctive word. Thirdly, Napier's *differentiæ*, called by Kepler *mesologarithms* (being in Napier in the middle), are reprinted separately to every minute of the first ten degrees, for the sake of the latitudes of the planets. Fourthly, more accurate cosines 0 (10") 1° 40', are given.

1628. Adrian Vlacq, 'Arithmetica Logarithmica,' Gouda. The whole hundred chiliads of numbers, from 0 to 100,000, to ten decimals. Sines, &c., to every minute. This work very much displeased* Briggs's friends in England. On the one hand the work is called a *second edition* of Briggs; and, being all in numerals and in Latin, it needed no translation. The pretexts were, first, that copies were scarce in Belgium, which was bad: and that Briggs had omitted the logarithms from 20,000 to 90,000, which was good. On the other hand, it may be held that the supplying of this defect made a new work of the whole; and that the description of it as a second edition of Briggs was too large a concession. A middle course ought to have been taken: Briggs ought to have been consulted. Had this been done, an arrangement would probably have been made which would have satisfied all parties. The error, if any, was purely commercial: there is nothing the least resembling literary plagiarism, but rather the opposite fault, over ascription.

(1630). Bartschius. The tables which Bartschius published independently of his father-in-law (Kepler) had fallen into oblivion, when Eisenschmidt found a copy and republished them with Kepler's *last* tables, and with interscript differences, under the title of 'Joh. Kepleri et Jacobi Bartschii Tabulæ manuales logarithmicæ,' Strasburg, 1700, 12mo. What the titles and dates of the original works were, we can find only from Lipenius, who gives them as follows:—

> Jac. Bartschii 'Tabulæ Novæ Logarithmico-logisticæ,' Leipzig, folio, 1635; and 'Trichil. Hexacosias Logarithmi.' Sagan, 8vo, 1630.

Whether the first was an original edition we do not know: if so, it was posthumous. The reprint by Eisenschmidt contains (from Ursinus, see 1624) a table of logarithmic sines to six figures, 0° (10") 24° (15") 48° (20") 69° (30") 82° (1') 90°; a table of logarithmic tangents 0° (10") 90°, called *mesologarithms;* a more accurate table of logarithmic cosines 0° (2") 2° 7'; an astronomical table which it is not in our plan to describe; and a table called *Trichil-Hexacosias logarithmorum logisticorum*, being a table of what are still called logistic logarithms with 1" and 24^h for first terms.

(1630). J. Faulhaber, 'Ingenieurs-schul., Erster Theyl,' Frankfort. This work contains logarithms, according to Scheibel, who does not give a description.

1631. Norwood, 'Trigonometrie.' Logarithms to seven places; numbers to 10,000, sines, &c. to every minute. We do not know the date of the first edition of Norwood's 'Epitomie': there is one of (1645) (Wilson) and we have one of 1659. The tables are of five decimal places, 0 (1') 45° and 0 (1) 1000; with a separate title 'A Triangular Canon Logarithmical.'

1632. Cavalieri, 'Directorium Generale Uranometricum,' Bologna. Eight-figure logarithms, the ten first thousand numbers in columns of twenty: the sines, &c. to various divisions in different parts of the quadrant. It is very convenient to have a short mode of denoting change of intervals; the following could hardly be misunderstood:—Cavalieri's tables are, 0 (1") 5 (5") 10' (10") 20' (20") 30' (30") 1° 30' (1') 45°. The table of logarithmic versed sines is said to be the first given. Cavalieri gave logarithms again in his trigonometry (see 1643); and also in his 'Tabula Trigonometrica,' of which we do not know the date.

1633. Gellibrand, 'Trigonometria Britannica,' Gouda. Briggs's work, which he did not live quite to complete. Sines, tangents, and secants, with logarithms of the sines and tangents: sines to fifteen decimals, tangents and secants to ten, logarithms of sines to fourteen decimals, logarithms of tangents to ten decimals. It is to hundredths of degrees, not to minutes.

1633. Vlacq, 'Trigonometrica Artificialis,' Gouda. Logarithms of sines, tangents, and secants, to every ten seconds, and to ten places of decimals. Twenty thousand of Briggs's logarithms of numbers are added.

1633. Nathaniel Roe, 'Tabulæ Logarithmicæ,' London. Seven-figure numbers to 100 thousand, ten-figure sines, &c. to hundredths of degrees. The first table in which attempt at compression was made: the numbers are in columns of fifties, the first figures of the logarithms being at the top. A good model for a small and clear type. The explanations are called Wingate's, whose name is by the announcement made so conspicuous in the title-page, that the whole book must have often been attributed to him.

1633. J. B. Morin, 'Trigonometriæ Canonicæ Libri Tres,' Paris. Seven-decimal Logarithms; of Numbers 0 (1) 1000, with interscript differences; of Sines and Tangents 0 (1') 45°. The decimal point is not used.

(1634). Cruger. Kästner gives Dantzig as the place. The logarithms are Naperian, according to him.

1634. Herigone, 'Cursus Mathematicus,' vol. iii., Paris. Said to be the first digested course of mathematics; contains logarithms, apparently from Wingate's French of 1626.

(1634). Frobenius, 'Clavis Univ. Trigon.' The (by that time) usual Briggs's logarithms to seven places.

(1634). Cruger, 'Praxis Trig. Logarith. cum Logar. Tab.', &c., Amsterdam.

(1635). Cruger, 'Doctrina Astronomiæ,' Dantzig. Contains logarithmic tables.

1635. Anonymous, 'Logarithmeticall Table,' London. [Attributed to Wingate. Dodson is followed by Hutton in saying that Wingate published an English edition of his French logarithms. But Hutton never saw any prior to this of 1635, and we can find no mention of anything of Wingate's translated from French, except (in an old catalogue which gives no dates) 'The Construction and Use of the Logarithmeticall Tables,' not tables themselves. The logarithms of the table now before us are of six figures, and for the first time units' figures are at the head of the columns, and the tens down the margin. There are tables of 1632, attributed to Wingate.]

We allow the preceding paragraph in [ ] to stand as in the 'Penny Cyclopædia,' in illustration of the difference between the utmost that can be got from second-hand sources, and the results of a look at the original. We have found a copy of the following work:—'*Λογαριθμοτεχνία*, or the Construction and Use of the Logarithmeticall Tables, ... first published in the French Tongue by Edmund Wingate... and, after translated into English by the same author. The third Edition, diligently corrected and enlarged by the Author himself,' London, 1648, 12mo. The work is the letter-press of Wingate of 1625 and 1626, already noticed, translated into English. The tables have a French title of 1635, 'Une table logarithmique... Imprimé à Londres.' But our separate copy of the tables, being that which heads this article, has an English title, though both tables are from one type. No doubt the first edition was of 1635, and the supply of tables lasted several editions of the supply of text. Wingate was a wealthy man, and probably found his disposition to alter and amend his descriptions outrun the sale of the work. But the tables are not reprints of the French tables of 1625. They are to six figures, not seven; the numbers are 0 (1) 10,000 ranged by double entry, three digits and one: and the trigonometrical tables are arranged in a manner more like that now in use.

1635. Henry Gellibrand, 'An Institution Trigonometricall,' London. Seven decimals; logarithms of numbers 0 (1) 10,000; sines, tangents, and secants, with logarithms of sines and tangents, dividing the page into two parts, one of three columns, the other of two. The form not semiquadrantal, but quadrantal, with the complemental degree (inverted) on the opposite page. No differences; some subsidiary tables for astronomy and navigation; the name of Briggs prefixed to the logarithms of numbers only. This is the form of a series of tables which ran through many continental editions; but they all bear the name of Vlacq. It is stated that Vlacq's first edition of them appeared in (1636): and Dechales (i. 22) describes a work of Vlacq of precisely the above contents, as of Gouda (1636). Early editions of small works are often lost to history. Now we have seen that Vlacq was a rapid appropriator of English ideas: in less than four years he reproduced Briggs, with the 70,000 missing logarithms, and a table of sines, &c. We must suppose that he seized upon Gellibrand's form, and immediately reprinted it. We have seen (1626) that Vlacq's previous idea of a small table had been very different.

The originator, then, of the long succession of small tables is Gellibrand. All the tables of this *Gellibrand model* are known at a glance by containing, on one page, sines, tangents, secants, with logarithms of sines and tangents, and some *white* between the sines, &c., and the logarithms. Under the name of Vlacq, his idea prevailed till 1760, when Lalande first commenced a new series. Lalande himself originated a third series in 1805; and the next series begins, for England, with the reprint of Lalande by the Useful Knowledge Society in 1839. Schulze speaks of some small tables by Wolf, as being as common in Germany as those of Vlacq: of these we do not remember to have met with a copy.

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* Norwood, in his Trigonometry (preface dated November 1, 1631), reminds his readers that when he quotes the 'Arithmetica Logarithmica' he means Briggs's book of 1624, not that put forth a month since in English (see *ante*, 1624, Briggs), "being nothing like his, nor worthy his name." He blames Vlacq for his "second edition" of Briggs's work, against Briggs's "mind and liking," which he says frustrated the second edition of the original, besides omitting some things of special moment.

1643. F. B. Cavalieri, 'Trigonometria plana et sphærica,' Bologna. Seven-decimal Briggs's logarithms 0 (1) 1000, with interscript differences; also sines, tangents, secants, and their logarithms, 0 (10″) 30′ (30″) 1° (1′) 45°. But the decimal point is not used. The logarithms of sine, tangent, secant, are styled logarithm, mesologarithm, tomologarithm.

1651. Vincent Wing, 'Harmonicon Coeleste,' London. The logarithms have separate title-pages, and might, if torn out, pass for separate works. They have the decimal point and are to six decimal places. Sines and tangents 0 (1′) 45°; numbers, in decads, 0 (1) 1010, without characteristics. Wing was a much more learned man than his reputation (which is that of an almanac-maker) would imply.

1654. John Newton, 'Institutio Mathematica,' London, 2 vols. 12mo. Contains tables.

1657. Oughtred's 'Trigonometrie,' London, published both in English and Latin in the same year. The logarithms however are from the same type, with the Latin title in both: they are complete six-figure logarithms; the numbers, which go to 10,000, having seven figures. The trigonometrical part contains sines, tangents, and secants, with the logarithms of sines and tangents. The table is quadrantal, the supplemental degree being in the opposite page inverted. It divides the degree into 100 parts, though each part is called a *minute*.

(1657). John Newton, 'Help to Calculation,' &c., for converting sexagenary tables into decimal by logarithms.

1658. John Newton, 'Trigonometria Britannica,' London. The logarithms of sines, &c., are 0 (0°·001) 3° (0°·01) 45°, to 8 decimals; also sines to 15 and logarithms of sines to 14 decimals, 45° (15′) 90°. The logarithms of numbers are thrown into the form which they have ever since preserved in seven-figure tables. But, instead of differences to the logarithms of numbers, five-decimal logarithms of differences are given.

1668. John Newton, 'The Scale of Interest, or the use of Decimal Fractions.' Here is a table of logarithms to six decimals 0 (1) 10000 arranged in lines of decads, with a separate table of proportional parts. This is the first attempt at a school-book and a workman's book. There is an appendix of application to carpentry and gauging.

1669. Phillippes, 'A Mathematical Manual.' Six-figure logarithms, common and trigonometrical without secants or cosecants, 0 (1) 10000, 0 (1′) 45°.

1679. 'A table containing ten Miliads....' and 'A triangular Canon Logarithmical,' London. Seven-decimal tables, numbers 0 (1) 10,000, and sines, tangents, and secants 0 (1′) 45°. These tables belong to some work, from which our copy is cut out: signatures from Aaa to Ttt, quarto.

1681. Vlacq, 'Tabulæ Sinuum, &c., Amsterdam: also 1683. Vlacq, 'Tables de Sinus,' &c., Amsterdam; and 1689, Vlacq, 'Tabellen der Sinuum, &c.,' Amsterdam. These have the same introduction, one in Latin, the other in French, the third in German, have sines, tangents, secants, and logarithms of sines and tangents, to every minute and to seven decimals. Also, seven-decimal logarithms from 1 to 10,000, headed 'H. Briggii Tabula Logarithmorum.' The first and second are different prints; and that of 1683, which passes for the most correct (see 1697, Ozanam), is in a beautifully legible bold type, large for so small a book. There are those who would be glad to use it now. See above, at the year 1635, Gellibrand.

1681. Jonas Moore, 'New Systeme of the Mathematicks,' London, 2 vols. 4to. In the second volume, as part of an extensive system of tables for navigation, are found tables of logarithms of numbers to seven decimals 0 (1) 10,000, with tables of proportional parts 44 (1) 4320; sines, tangents, and secants, and their logarithms 0 (1′) 45°. Also, for the first time in England, a complete minute-table of natural and logarithmic versed sines.

1685. Ozanam, 'Tables des Sinus,' &c., Paris. This is really Vlacq in every particular as to the tables, though his name is not mentioned. The tables are attached to a work on trigonometry. Many a writer thought that the body of this work consisted in his own trigonometry, or surveying, &c., and that the table was an accessory of which no notice need be taken. And so, in our own day, many persons who are quite above plagarism of text think it no sin to borrow plates or diagrams without acknowledgment.

1690. Dechales, 'Cursus seu Mundus Mathematicus.' The first volume has seven-decimal tables; logarithms of numbers 0 (1) 10000; of sines and tangents 0 (1′) 45°, and the sines and tangents also.

1690. Wm. Leybourn, 'Cursus Mathematicus.' This book has internal evidence of having been written before 1660. Seven-decimal logarithms of numbers 0 (1) 10000; six-figure logistic logarithms 0 (1″) 1° and 1° (1′) 1° 12′; *signs*, tangents, and secants, &c., 0 (1′) 45°; the names cosine and secant not used.

1697. Ozanam, 'Tables des Sinus,' &c., Paris. This is a reprint (see 1685) without trigonometry, and Vlacq is acknowledged. The printing is from the edition of the Hague, 1665, which ranks amongst the most correct; the correction from that of Amsterdam, 1683, which passes for the more correct. Two years afterwards, in 1699, the tables only were reprinted (Paris), the name of Vlacq was restored to the title-page, and the 'Au Lecteur,' written by Ozanam in 1697, was added at the end.

1699. John Wing (nephew of Vincent), 'A compleat Body of Surveying, formerly publish'd by Vincent Wing,' London. Five-decimal logarithms of sines and tangents, 0 (10′) 45°; of numbers, 0 (1) 1000.

(1704). J. H[arris], 'Table of Logarithms,' quarto, mentioned in Hutton's sale catalogue.

1705. (Second edition.) Anonymous, 'A Table of Logarithms for Numbers increasing in their natural order, &c.,' London. Six-decimal logarithms of numbers 0 (1) 10000. The trigonometrical part has a separate title, 1704, 'A Triangular Canon Logarithmical,' London. Six-decimal logarithms of sines, tangents, and secants 0 (1′) 45°. So far as appears, this table was got up by J. Seller and C. Price, mathematical-instrument makers, who seem to have desired to sell their own table of logarithms as well as their own quadrants. This table appears to be a second edition, so called, of a table precisely resembling it, except only in having seven decimals, attached to the 'Practical Navigation' of the same John Seller, who appears as the *author*.

(1706). Sherwin, 'Mathematical Tables,' London. The first work, we believe, in which the proportional parts are in the same page with the logarithms; and the common differences in the trigonometrical logarithms made *common*. Second edition, 1717; third, revised by Gardiner, and the best, 1742; fifth and last, 1771, very erroneous—the most inaccurate table Hutton ever met with.

1710. John Harris, 'Lexicon Technicum,' vol. ii. This volume contains seven-decimal tables of logarithms 0(1)10,000, and a complete canon (including versed sines), 0(1′)45°, both natural and logarithmic. There is also a table of proportional parts for every integer from 44 to 4320. These tables, except the last, seem to be taken from Sherwin.

1717. Abraham Sharp, 'Geometry Improved,' London. A large table of areas of the segments of circles: but it contains logarithms of all numbers to 100, and all primes under 1100, true to sixty decimals; 63 decimals of logarithms 999990(1)1000000 with differences to the tenth; and 63 decimals of the logarithms 1000001(1)1000010. Also an immense mass of results on the regular solids.

(1721). 'Magnus Canon Logarithmorum .... Typis Sinensibus in Aula Pekinensi jussu Imperatoris excusus.' In this year was printed at Pekin, by command of the emperor Kang-Hi, in Chinese type and in three folio volumes, Vlacq's logarithmic tables of sines, &c., to ten seconds, and of numbers to 100,000. (Vega, who had seen a copy at Vienna.) The Royal Society possesses some Chinese logarithms, and, as usual, there were in 1827 some who believed that the Chinese had possessed logarithms from all eternity. Mr. Babbage ('Astron. Soc. Notices,' vol. i. p. 9), examined these tables, and found that six slight errors which run through most European tables were committed in them. Only Vega and the last impressions of Callet were free from these errors. It appears that the Chinese, according to their usual practice, had taken from the European work republished at Pekin, without any allusion to the source.

1741. Deparcieux, 'Nouveaux Traités de Trigonométrie Rectiligne et Sphérique,' Paris. Deparcieux is so much better known by his tables of annuities, that his other writings * are neglected. The tables are all to seven decimals (though the decimal point is not used). There are logarithms of numbers 0 (1) 20000; sines, tangents, and secants, &c., 0 (10′) 5 (1′) 45°, and logarithms of sines and tangents. This is the earliest table we remember to have seen in which the argument of degrees, minutes, and seconds accompanies the logarithms of numbers. The book is also distinguished by its gnomonical tables, and by the excellence of its solid diagrams.

1742. Dodson, 'Antilogarithmic Canon,' London. This work was unique of its kind until 1849: it contains the number, to eleven figures, corresponding to every logarithm from ·00001 to 1·00000: the author † corrected the faults in most copies with his own hand. Harriot began such a table, according to Wallis, and Dr. Pell told Wallis that Warner had finished the table, and that it was in the hands of Dr. Busby, master of Westminster School. It was never published, and is probably lost. All our efforts to trace it, by help of published letters, &c., lead to the conclusion that, if existing, it must be among Lord Macclesfield's unexamined manuscripts at Shireburn Castle: this is by no means improbable.

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* When a person is distinguished by one particular work, his other, and particularly his previous, writings, even on the same subject, go out of notice. How many persons, for instance, know that Laplace published (separately from the Memoirs of the Academy) a small work on the elliptic motion and on the figures of the planets in 1784? (See Lalande, Bibl. Astron. ann. 1784.) And how many biographical accounts of Laplace mention it?

† In the Phil. Mag. for 1853 are extracts from the diary of Reuben Burrow, who states that Robertson (the author of the Navigation) told him that William Jones (better known than his son among the mathematicians) wrote Dodson's preface, because Dodson wrote such a confused style that it had neither head nor tail. This was not the case, as any one may see: unless indeed Dodson got a friend to write all he published. But there is also something like a charge of plagiarism on a different matter; and there are imputations against other persons. We do not object to the production of old diaries; but when they contain imputations, it is of importance that their authors should be truly painted. Burrow's biography, extracts from which accompany those from the diary, does no more than allude to "*eccentricities in private life which frequently attend genius*," and "habits formed by casualty and the necessities of the moment, rather than by design and the prudent hand of a master." The truth is that Burrow, a very able mathematician, was envious and foul-mouthed to an extent which it would be an insult to thousands of self-elevated men to palliate by the plea of want of early education. Of this we shall give an instance. Green and Wales, two very worthy as well as able men, were successively the astronomers who accompanied Captain Cook in his voyages: probably Burrow had been a competitor for the post. In his copy of any book published by either of them, Burrow usually wrote some scurrilous aspersion, of which we have seen several

1742. Gardiner, 'Tables of Logarithms,' London. Numbers 1—100100, sines, &c., 0 (1″) 72′ (10″) 45°, all to seven places, with logistic logarithms, and logarithms 0 (1) 1143 and 101000 (1) 101139, and numbers to logarithms ·00001 (·00001) ·00139, to twenty decimal places. Rare, and much esteemed for accuracy: the author[*] corrected the faults with his own hand. Few copies were printed.

1742. Anonymous, printed by J. F. Gleditschen, 'Des vollständigen Mathematischen Lexici zweyter Theil,' Leipzig. Here we have squares and cubes 0 (1) 10,000; seven-decimal logarithms of sines, tangents, and secants 0 (1′) 45°; logarithms of numbers 0 (1) 20000; sines, tangents, and secants 0 (1′) 45° to seven decimals; factors of odd numbers not ending with 5, to 10,000.

1743. Rivard, 'Tables des Sinus, &c.,' Paris, with the official "approbation" of Clairaut. Seven-decimal logarithms of sines, tangents, and secants 0 (1′) 45°; sines and tangents to five decimals; secants in a separate table; logarithms of numbers 0 (1) 20000: all with characteristics and no decimal points.

1747. James Dodson, 'The Calculator .... adapted to Science, Business, and Pleasure,' London. A large collection of small tables, with sufficient, though not the most convenient, seven-figure logarithms. If a person of varied mathematical pursuits wanted a book, say for travelling, he would not easily find one which would answer more purposes at a pinch than the one we now speak of. The contents are too varied for enumeration.

1757. In the original articles there was a gap from 1742 to 1770, which shows that there was a lull in the publication of pure mathematical tables. The period was one in which the mathematicians were very much absorbed in physical investigation. When this is the case, tables of pure mathematics find their way into works of physics and astronomy under headings of application. Should any one ever enlarge upon our plan, he must search astronomical and other works for such tables as the following: Thomas Barker, 'Account of comets .... with new tables,' London, 4to., 1757. The tables give, for focal distance unity, and for angles of anomaly 0 (5′) 180°, the distance of a point from the focus of a parabola, and the area of the sector on the supposition that at 90° the sector is 100°. Halley had given a table of the same kind on a much smaller scale: and Euler, in the 'Theoria Motuum Planetarum,' in 1744, had given the area of the parabola for each degree of anomaly. Professor Schumacher (September 3, 1846), wrote to us as follows: "Professor Knorre has sent me this (Barker's) table, calculated from 0° to 180° of anomaly, from 10″ to 10″ (like Callet's sines), to see if I can get it printed. It is a work of immense labour, executed by Mr. Rupertus in Russia. The booksellers, of course, will not undertake it." We have heard nothing more of this table. More tables than we think it desirable to describe here, on the ellipse, parabola, and hyperbola, as orbits of a comet, are given in 'Methods of computing the Orbit of a Comet or Planet,' being the appendix to the third volume of Bowditch's translation of the 'Mécanique Céleste,' Boston (U.S.), 1834, 4to.

(1760). Lacaille and Lalande first published a small table: Marie reprinted it in 1768: there were editions in (1781, 1791, 1799). So far Lalande, in his preface of 1805 (see that year): none of these works have come to our hands.

1770. J. H. Lambert, 'Zusätze zu den Logarithmischen und Trigonometrischen Tabellen.' This is a miscellaneous collection of tables and formulæ, containing—Primes, at least divisors of all odd numbers which do not divide by 3 or 5, up to 102,000; three-digit terminations of odd squares: first ten multiples of all prime numbers up to 313; primes alone up to 102,000; powers of 2 as far as the 70th, and of 3 and 5 as far as the 50th; hyperbolic logarithms, seven decimals, 0 (1) 100, and 1 (·01) 10, and 1 (1) 10 to 25 places; numbers which divide by 2, 3, 5, or 7 only, or their powers or products (except those which divide by 2 or 3 only), up to 10,000; sines of 3° and its multiples expressed quadratically; cyclometrical ratio; 27 decimal arcs 0 (1°) 100° (20°) 120° (30°) 360°, and for minutes and seconds; five-decimal sines and nine multiples 0 (1°) 90°; seven-decimal sines, tangents, and secants, and logarithms of sines and tangents 0 (1°) 90°; tables for facilitating cubic equations; sines and cosines of *hyperbolic trigonometry*, the only table of the kind we have met with; squares and cubes 0 (1) 1000; figurate numbers to the 12th order, 30 of each; eight-decimal powers of fractions 0 (·01) 1 to the 11th power; seven-decimal square roots 0 (1) 100; with smaller matters and many algebraical formulæ of development. There is said to be another edition of this useful miscellany, Lisbon (1798).

1770. Reprint of Gardiner at Avignon, by Pezenas, Dumas, and Blanchard, with the first four degrees to single seconds, from a manuscript which Mouton had bequeathed to the Academy of Sciences. The three industrious editors, all of them priests, who found time to complete this useful undertaking, modestly withheld their names; but Lalande, who was in communication with them, and who was an old pupil of Dumas, has recorded them. There was a reprint of some sort at Florence, in (1782), and we have been informed of a third Italian edition, so-called, Florence (1810), badly printed, and containing also logarithms of prime numbers up to 6607, to twenty figures.

(1772). Gherli's 'Logarithms,' Modena. Very much the same as Hutton's in their contents.

1775. Douwes 'Tafellen behelzende de Sinussen .... als mede de Logarithmen,' &c., Amsterdam. A complete minute-canon to seven decimal places; followed by logarithms to seven places; versed sines and logarithms on the same scale to 90 degrees; logarithms of numbers from 1 to 101000; and traverse tables.

1778. J. C. Schulze, 'Neue und erweiterte Sammlung logarithmischer . . . Tafeln,' Berlin. Also, 'Recueil de tables logarithmiques . . . .' The titles and preliminary explanations are both in French and German. Two volumes. This is a valuable and original collection. It contains the usual seven-figure tables 0 (1) 101000; a page of multiples of ·434 . . . and its reciprocal to 48 places, and powers of 2·718 . . . to 28 figures; *Wolfram's*[*] hyperbolic logarithms of all numbers from 1 to 2200, and from thence to 10,000 for all numbers not divisible by any single digit, all to *forty-eight decimal places;* common logarithms to seven decimals of sines and tangents 0 (1″) 2°; logistic logarithms to four decimals 0 (1″) 1°; a complete canon 0 (10″) 4° (1′) 45° containing sines, tangents, and secants to seven decimals, common logarithms of sines and tangents to seven decimals, *Naperian* (not hyperbolic) logarithms of sines and tangents to eight decimals; first nine multiples of sines of every degree to five decimals; lengths of arcs 0 (1°) 360° to twenty-seven decimals; ditto 0 (1′) 1° and 0 (1″) 1′; powers of fractions 0 (·01) 1 as far as the eleventh, to eight decimals; squares and cubes 0 (1) 1000; square and cube roots 0 (1) 1000 to seven decimals; binomial coefficients 0 (·01) 1 to six factors; a table for the fall of bodies, of rational right-angled triangles with the angles, and small tables of specific gravities and of weights and measures. Half-a-dozen of Wolfram's logarithms which were accidentally missing in consequence of an illness, are supplied in the Berlin Ephemeris for 1783, p. 191. The *Naperian* logarithms of sines and tangents are an abbreviation of Ursinus, (see 1624).

(1783). Vega 'Logarithmische Trigonometrische und andere . . Tafeln und Formeln,' Vienna. This was Vega's first work, and we have never met with it. (Octavo.)

1783. Callet, 'Tables Portatives de Logarithmes, publiées à Londres par Gardiner,' &c., Paris. The first edition of Callet, as it is called, was really made from Gardiner's tables "augmentées et perfectionnées dans leur disposition par M. Callet." Callet added as much of each kind of table as would leave no white in his last page, and, from Mouton, completed the single-second table of sines and tangents up to 2°. Here also first occurs the broken line at the change of the third figure. On this edition Hutton, commonly said to have much prejudice against French men and things, says "it is but justice to remark the extraordinary spirit and elegance with which the learned men and the artisans of the French nation undertake and execute works of merit:" and the compliment is well deserved by the beauty of the type and the general accuracy of the work. The contents are seven figure logarithms of members 0 (1) 102960, of sines 0 (1″) 2°, of sines and tangents 0 (10″) 45°; logistic logarithms; logarithms to twenty decimals 0 (1) 1000 and for primes up to 1161; also for 101000 (1) 101179 with three orders of differences; 20 figures of numbers to logarithms ·00001 (·00001) ·00179 with the same differences; hyperbolic logarithms to seven decimals 1 (·01) 10·59.

1795 (new tirage, 1821, with many errors corrected). Callet,

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instances. But in the 'Misc. Scient. Cur.,' of which Green and Wales were co-editors, he felt that the conjunction of his luminaries demanded a spring-tide, and he accordingly wrote the following eccentricity of genius in private life on the fly-leaf of his copy, now before us, and left it to posterity:—"Miscellanea Scientifica Curiosia, or a Balderdash Miscellany of damn'd Stupid, Raggamuffin, Methodistical Nonsense and Spuability. By two of the most stupid and most dirty of all possible Fools, Rogues, and Scoundrels; viz^{t}., John Green, A.M., late Tub-thumper, now Soul-driver in Hell; and William Wales, — brusher at Christ's Hospital, not only the dirtiest Scoundrel that God ever made, but the dirtiest rascal that he possibly could make. Amen." There are other notes in the book about these persons and others as well; but this is enough. The reader will excuse the production of such coarseness, in consideration of the expediency of fixing the value of extracts made, or to be made, from Burrow's diary.

[*] The work had a small list of very influential subscribers. Of about 120 names of persons and institutions in the list, one in three is the name of a person now known by name to any smatterer in scientific and literary history. Few subscription lists would give such a result after a century of existence. The work thus recommended makes an epoch in the history of tables.

[*] This table was the work of Lieut. Wolfram, of the Dutch artillery, and took six years of hard labour. It is one of the most striking additions to the *fundamenta* of the subject which has been made in modern times. Delambre ('Hist. Astr. Mod.,' v. i., p. 501, &c.) introduces his comparisons of Napier and Wolfram so abruptly, and so many pages elapse before the reader can find out who the latter was, that most probably many have inferred that the two were contemporaries. But this is Delambre's way, and is often liable to confuse a reader who has no warning on the subject. With a work before him from which he is drawing his materials, he perhaps never mentions it till the end of his remarks, or perhaps casually in the middle, though until such mention is made, all he says is very liable to be misunderstood.

'Tables Portatives,' &c., Paris. Two volumes. This second edition, *stereotyped* by Firmin Didot, is one of the most correct and convenient as well as extensive works in existence: many persons prefer it to any other. It contains the usual seven-figure logarithms from 1 to 108000—common and hyperbolic logarithms, each to 20 decimals, up to 1200—logarithms, common and hyperbolic, to 18 decimals, with first, second, and third differences, from 101000 to 101179—numbers to logarithms, common and hyperbolic (to 20 figures), from ·00001 to 00179, with the same differences; common logarithms[*] to 61 decimals, and hyperbolic to 48, to all numbers from 1 to 100 and all primes to 1097; the same for numbers from 999980 to 1000021—multiples of 2·30258 . . . and ·43429 . . . . to 100 times—arcs to 25 decimals, for both sexagesimal and centesimal division—seven-figure logarithmic sines, &c. for each minute of the centesimal division—sines (15 decimals) and their logarithms (the remaining places up to 14, the first seven being in the last table) for centesimal degrees and tenths—proportional parts—sexagesimal seven-figure logarithms of sines and tangents 0 (1″) 5° (10″) 45°—logistic logarithms. Those tables are tolerably, but, we believe, not extremely, correct in all parts, except in the latest tirage. The tirage of 1827, on yellow paper, was taken to accompany Mr. Babbage's logarithms.

1784. M. Robert, curate of St. Geneviève à Toul, sent Lalande ('Ency. Meth.' Tables.) a manuscript volume containing sines to every second, to how many places he does not say; shortly afterwards he sent the tangents. Lalande gives a hint that the approaching publication of Taylor's logarithms prevented any steps being taken to print these. He also states that there was in the library of the Academy of Sciences a manuscript of Mouton, giving the logarithmic sines and tangents of 0 (1″) 4° to eleven figures; we suppose he means to ten places of decimals (see 1770). M. Robert's manuscript came into Delambre's possession, and was bought at the sale of his books by Mr. Babbage, in whose possession it now is. It is in two large folio volumes, the figures (to seven decimals) being written in printed skeleton columns. Some corrections of Callet, discovered by means of this manuscript, were printed in one of the nautical almanacs.

1785. Hutton, 'Mathematical Tables,' London. Many editions, the second in 1794; one in 1849. A very correct set, with sines, tangents, &c., and versed sines, complete, both natural and logarithmic. For those who want seven places, and can have but one book, there is none better. The additional matters, especially the historical introduction, are well-known.

1789. William Garrard 'Copious Trigonometrical Tables.' This is one of the largest of what are called in navigation *traverse tables*. For every integer hypothenuse from 1 to 300 are given, to two decimals, the value of the base and altitude, for every angle 0 (10′) 90°.

1792. Michael Taylor, 'Tables of Logarithms,' London. In the trigonometrical part the sines and tangents are *to every second*. The errata of this work have been published in various nautical almanacs. This widely used work, the first to which 0′ (1″) 90° applies, was by a most industrious computer, attached to the staff of the 'Nautical Almanac.' He died just before the last half sheet was printed; and Dr. Maskelyne supplied the introductory matter. This book, like others published by the Admiralty, was not sufficiently advertised. It sold as a second-hand book, neither sellers nor buyers knowing that Mr. Murray had plenty on hand. For ought we know, the same thing may still go on.

1791-1807. Maseres, 'Scriptores Logarithmici,' London. The first volume contains a reprint of Kepler's Logarithms, the sixth and last of Napier's work of 1614, and John Sperdell's logarithms of numbers.

1794 or 1795. (an III., a Port-Malo, chez L. H. Hovius, fils) Tables des logarithmes des nombres, depuis 1 jus qu'à 10700 . . . . dresseés á l'usage de la navigation . . . . Six figure logarithms of the common type, in all respects but one, and that one curious and perhaps unique. A rectangle which *corners* with the upper right of the page, has an extent of 30′ with the usual semi-quadrantal arrangement of trigonometrical logarithms. In the remaining gnomon comes a part of the table of logarithms of numbers. At ninety of these to a page, the logarithms of numbers come so near in the book to the corresponding figures in the sines and tangents, up to 45°, that a person who wants the natural sine or tangent has very little turning of pages to do. But this is no help to the second half of the sines, or the first half of the cosines. When the half-quadrant is finished, the remaining logarithms of numbers ran on in the usual way. Had the author made a full quadrantal arrangement, and checked the speed of his logarithms of numbers a little, by additional lead or otherwise, as he went on, he might have made something which would possibly have been judged worthy of imitation, in tables specially intended for astronomers and other trigonometers.

1795. The Abbé Borne, a Frenchman, gave a table of logarithms of numbers of a peculiar kind at the end of his 'Principie ragionati de Aritmetica,' Pesaro, 8vo. All numbers which end with 1, 3, 7, 9, are found by double entry; thus 6973 is in column headed 69, and row fronted 73. If this were a prime number, seven decimals of logarithm would have been entered: as it is, the lowest divisor, 19, is entered. Thus, in 20 pages there is a *potential* table 0 (1) 10,000. But the Abbé did not see that the same space would have contained the logarithms of all odd numbers not ending with 5: and these, with the logarithms of 2 and 5 printed at the head of every page, would have done better service than the factors. Authors often forget that they do not save either space or cost of printing by what appear abbreviations or omissions in the manuscript: the saving is but so much of what the printer calls *white*, which is done by types; and white is black, both in the room it takes and in the printer's bill.

1794. George Vega, 'Thesaurus Logarithmorum completus,' Leipzig, folio. Vega's edition of Vlacq. See Vlacq of 1628 and 1633. A very correct work: a ducat was offered for every error detected. There is also a German title-page, and the explanations are both in German and Latin. This is, no doubt, up to this time, *the* table of logarithms; the one of all others to which ultimate reference should be made in questions of accuracy. Its contents are,—a *ten*-decimal table of common logarithms 1 (1) 101000 distributed in the common manner, a decad in each line of the double page, with the differences arranged in the same way, and tables of proportional parts for the first three figures of the differences. Logarithmic sines and tangents to 10 decimals, 0 (1″) 2° (10″) 45°. Sines 0 (1″) 12′ to ten decimals. Lengths of arcs to 11 decimals. Wolfram's *hyperbolic* logarithms (see 1778) above described, reprinted from Schulze.

1794. J. J. Girtanner, 'Logarithmische Tafeln zur Abkurzung kaufmannischer Rechnungen,' commercial logarithms. The plan is to have logarithmic tables for integers and different sorts of fractions, among which eighths, tenths, sixteenths, and sixtieths are conspicuous. But it will not do: Mohammed must go to the mountain. When coinage, weights, and measures, are decimalised, the use of logarithms will follow as a matter of course. It is useless trying to bring logarithms to ordinary fractions.

1797 (2 vols. 2nd ed., or rather second work) and 1812. Vega, 'Tabulæ Logarithmico-Trigonometricæ,' Leipsic. Titles and introduction both in German and Latin. The usual logarithms of numbers, 0 (1) 101000; logarithms of sines 0 (0″·1) 1′, and 0 (1″) 1° 30′, and the full canon 0 (10″) 6° 3′ (1′) 45°—divisors and primes already noticed—eight-figure hyperbolic logarithms from 1 to 1000, and for all primes up to 10,000—powers of 2·71828, and their common logarithms (from exponent ·01 to 10·00). First ten powers of numbers up to 50; squares and cubes of numbers up to those of 1000, &c.,—logistic logarithms, binomial co-efficients, and astronomical tables various. There are various smaller editions from Vega, as at Leipsic (1820), and (1826).

1799. J. P. Hobert and L. Ideler, 'Nouvelles Tables Trigonométriques calculées pour la Division décimale du Quart de Cercle,' Berlin. Delambre speaks highly of this table; but he is wrong in saying it subdivides the quadrant as minutely as those which himself and Borda published. Meaning by 1° the hundredth of the right angle, and 1′ being 0°·01, and so on, Hobert and Ideler's division of the quadrant is 0 (10″) 3° (1′) 50°; but Delambre and Borda's are as below. The Berlin table gives sines and tangents and their logarithms, through the quadrant; the Paris table gives logarithms only. The former has no logarithms of numbers except 0 (1) 1100 and 999980 (1) 1000021, all to 36 decimals.

1800 or 1801. (An. IX.) Delambre and Borda, 'Tables Trigonométriques Décimales,' Paris. These tables were corrected from the grand 'Tables du Cadastre,' still unpublished.[*] [PRONY, in BIOG. DIV.] They contain, the common logarithms of numbers to seven decimals, 11-decimal logarithms of numbers from 1 to 1000, and from 100,000 to 102,000°; 11-decimal logarithmic sines, cosines, tangents, and cotangents 0 (10″ centesimal) 10′ and 0 (10′) 100; 11-figure hyperbolic logarithms from 1 to 1000; 7-decimal logarithms of sines and tangents 0 (1″) 3° (10″) 40° (1′) 50° centesimal.

1802. J. R. Teschemacher. 'Tables calculated for the Arbitration of Exchanges, both Simple and Compound,' London. This is a book of commercial *logarithms*, though the author wisely avoided frightening the merchant by mentioning the word in any part of his book. There is one table of logarithms for the exchange between London and each other place: the tables average about a page each. With this limited range, the logarithms are really effectively applied to commercial purposes, and operations are very much simplified. There is no need of a separate book of logarithms: all that the reader knows or needs to know is that certain nameless figures are to be used in a certain easy way. We are fully of opinion that such a work might be very useful.

1804. De la Caille, De la Lande and Marie, 'Tables de Logarithmes,' Paris. Six decimal places, which probably the preceding ones had, (see 1760). The trigonometrical tables 0 (1′) 45° as usual, with differences for 1″: the numbers 0 (1) 21600. La Lande has forgotten to mention this edition; or perhaps it was not published when he was preparing the work next mentioned.

1805. De la Lande, 'Tables de Logarithmes,' Paris. *Stereotyped.* See 1760, 1831.

1806. Thomas Whiting. 'Portable Mathematical Tables,' London. Six-figure logarithms. This book is a striking proof that in the old figure, the reduction of the thickness of the type very much increases the legibility. This is a very easy book to read, and would exactly suit those who want a large type in a small book.

[*] The last 51 places are given, the first ten being accessible in a former table.

[*] There was once a commencement of the printing, and we have seen some of the proofs.

1808. Ebert. 'Adriani Vlacq Tabulæ Sinuum,' &c. Leipzig. The contents are as before described (1635). This is a new (and apparently the last) edition of Ebert's, whose preface is dated 1790. Besides the contents above described there are logarithmic sines and tangents for each second of the first degree, and squares and cubes of all integers up to 1000.

1809. George Douglas. 'Mathematical Tables,' Edinburgh. A long preface; followed by seven-decimal logarithms from 1 to 10,000, ten in a line, in the usual way. Two supplemental tables, with the same from 10,000 to 11,000, and from 100,000 to 101,000. A complete logarithmic canon for minutes, to seven decimals. A corresponding canon of natural sines, &c. Natural and logarithmic versed sines, the former to 90°, the latter continued to 180°. A table to convert sexagesimals into decimals; and logarithms from 1 to 180, to 15 decimals. A different arrangement from the usual one in several respects. No differences in any part of the tables.

(1812). In Zach's 'Monathliche Correspondenz,' vol. xxvi., page 498, Gauss proposed his logarithms for the finding of $\log(a+b)$ from $\log a$ and $\log b$ [LOGARITHMS, GAUSS'S], with a specimen. He stated that he had been in the habit of using five-figure tables of his own construction. Gauss has given a short review of Pasquich's tables (mentioned below, 1817) in the 'Göttingen gelehrte Anzeigen,' 1817, No. 158.

(1814). [Printed by] Firmin Didot, Paris. Six-decimal logarithms beautifully printed: numbers 0 (1) 21750; sines and tangents 0 (1′) 45°; $x \div \sin x$ and $\tan x \div x$ to 3°; sines, cosines, tangents, cotangents, 0 (0°·00001) 0°·03000 (0°·0001) 0°·5000.

1814. Barlow's Tables, London. Here are found eight-figure hyperbolic logarithms up to that of 10,000, calculated from the primes in Vega. They had been previously printed in Rees's Cyclopædia.

The factors, primes, &c. in this work have been already mentioned, and it also contains a table for the irreducible case of cubic equations, binomial coefficients, algebraic formulæ, specific gravities, &c. The reprint of 1840 contains only the squares, cubes, square and cube roots and reciprocals; but for these things it is the most accurate which exists.

1817. Thomas Preston, 'A new system of Commercial Arithmetic.' Sets of five-figure logarithms. In the first, the number is *also* represented as a number of pence, and turned into pounds, &c. Thus, 9701 has 40*l.* 8*s.* 5*d.* on the other side of its logarithm: this is carried as far as 130*l.* A similar table for avoirdupois pounds, as far as 5 tons. A table from 1 to 330, proceeding by twelfths: from 1 to 312, by sixteenths: and other tables of the same kind. This is one of the largest attempts of the kind.

1817. J. Pasquich, 'Tabulæ Logarithmico-Trigonometricæ contractæ,' Leipzig. Title and explanations in both Latin and German. Five-decimal logarithms of numbers 0 (1) 10,000; logarithms of sines and tangents 0 (10″) 56 (20″) 1°; five-decimal logarithms of sines and tangents, with a table of the *squares* of sines and tangents 0 (1′) 45°; *Gauss's Logarithms.* [LOGARITHMS, GAUSS'S.] The range of A is as follows, 0 (·001) 2 (·01) 3·40 (·1) 5. This trigonometrical canon of squares is, we suppose, almost unique.

1817. [E. A. Matthiessen], 'Tabula ad expeditiorem Calculum Logarithmi Summæ vel Differentiæ duarum Quantitatum,' Altona. It is to seven decimals, and A proceeds as follows: 0 (·0001) 2 (·001) 3 (·01) 4 (1) 5 (1) 7. But having only four figures of argument, the seven figures of tabular result are very troublesome to deal with, and the arrangement is not commodious. Gauss, in a letter to Schumacher, (September, 1846) writes as follows: (translated) "The English edition (referring to Mr. Peter Gray's work of 1849, then in progress) will no doubt correct the deficiencies which make Matthiessen's edition nearly useless. My tables are intended to make computation which can be made *without their help*, more *commodious* by their help. You must not have trouble to find what is to come out of the table, but you must find it in the most easy manner possible. This is not the case with Matthiessen's table, as I have shown in No. 474 of the 'Astron. Nachr.' There is another excess to be avoided: Matthiessen had not done enough. There is a parsimony of number."

(1818). Gruson's 'Logarithms,' Berlin. Contains also squares, cubes, square roots, and cube roots up to 1000.

1821. Nordmann, 'Adriani Vlacq Tabulæ,' &c. The explanations are given in Latin and German. To the contents of Ebert's edition (see 1808) are added square and cube roots to seven decimals for all integers up to 1000, the sines and tangents of the first degree being omitted. The form of the canon is modernised, and made completely semiquadrantal. This is called the *twentieth edition*, which very likely it is; but it was the editor's duty to have stated what the other nineteen editions were.

(1821). Westphal's tables, Leipzig, contain Gauss's tables, to five decimals, with proportional parts. (Schumacher)

1823. E. A. Matthiessen, 'Gemeine Logarithmen,' &c., Altona. *Stereotyped.* This table has five-figure logarithms from 1 to 10,000, with a supplemental table of proportional parts, arranged on the two sides of a folding sheet, on canvass.

1827. Babbage, 'Tables of Logarithms,' London. *Stereotyped.* Seven-figure logarithms of numbers only, now exceedingly correct. Printed on various coloured papers; Callet's stereotyped sines were at first printed on yellow paper in France to accompany them; but the French paper was of so bad a colour, that we believe the experiment was not continued. The tirage of 1831 is called a second edition, and copies on tinted paper are met with. In the preface are some conclusions as to the conditions of legibility, the results of trial, which are well worthy the attention of those who have tables to print. Mr. Babbage was, so far as we remember, the first who distinguished an augmented last figure from an unaugmented one: writing the contraction of ·12346 for instance, as $\cdot 123\dot{5}$. This example is now frequently followed. It secures an extreme nicety in certain rarely occurring cases: but we never found any practical balance to the inconvenience of a new symbol, except when the augmented figure is $\dot{5}$. We should recommend that an augmented 5 (Babbage's $\dot{5}$) should be printed v or V: all the advantage of an excellent but over-adopted suggestion would thus be received.

(1827). Salomon, 'Tables de Logarithmes,' Vienna. A large collection: contains also squares, cubes, square roots, cube roots, up to those of 1000; and divisors up to 102,011.

1827. Hantschl's Tables, Vienna. Ten-figure logarithms of primes up to 15,391; squares, cubes, square and cube roots, up to those of 1200; factors up to 18,277; and others.

1827. G. F. Ursinus, 'Logarithmi,' &c., Copenhagen. A complete six-figure table: rather common in England.

1828. Encke's four-figure Tables of Logarithms, &c., Berlin, contain Gauss's tables. See '1845, Warnstorff,' &c. below.

Logarithmen von vier Decimal-Stellen Berlin, 12mo. Four-figure logarithms, 0 (1) 1000, 0 (10′) 45°, without any name, letter-press, or date.

1829. Bagay, 'Nouvelles Tables Astronomiques,' Paris. An imitation of Michael Taylor's, logarithms of sines and tangents to every second. The logarithms of numbers are 0 (1) 21600. All to seven decimals.

1830. Hassler, 'Logarithmic, &c. Tables,' in a pocket form, New York. Seven-figure logarithms throughout: to half-minute intervals through the greater part of the tables of sines, &c. The logarithms of numbers broken as in Callet. We dislike this mode extremely; but many find it convenient.

1831. Lalande, 'Tables de Logarithmes,' Paris. *Stereotyped* in 1805; 1831 is the date of the first *tirage* with all corrections made. Five-figure tables throughout, and no mistake has ever been found in them, though it is said a reward was offered for any detection. There are, we believe, Brussels and other editions which have not the same character. The original work of Lalande, or Lacaille, Lalande, and Marie, had six places; last edition 1804; there was another, bearing the name of Lalande only, stereotyped in 1804. A similar table, with *seven* decimals, has been published for the use of students preparing for the Polytechnic School, and is sometimes furnished for the genuine Lalande: it is useless for ordinary purposes. If the English reprint of the tirage of 1831 (presently noted) be as correct, and no error has yet been found, it is much the better by type and paper.

1832. J. P. Gruson, 'Bequeme Logarithmische . . Tafeln,' Berlin. A school-book. Seven-decimal logarithms 0 (1) 10,000; squares and cubes, square and cube roots 0 (1) 1000; arcs of the circle; sines and tangents and their logarithms 0 (1′) 5° (10′) 45°.

1832. H. G. Köhler, 'Tables de Logarithmes,' &c. An edition of Lalande which gives Gauss's logarithms.

No date, (stereotyped,) Moritz von Prasse, 'Logarithmische Tafeln,' edited by Mollweide, and then by Jahn, Leipzig. Five-decimal logarithms of numbers 0 (1) 10,000; of sines and tangents 0 (1′) 45° put together in a new way, so as to separate the common figures, as in the logarithms of numbers, and to get five degrees into a double page, sacrificing the differences; Gauss's Tables, A having 0 (·001) 2 (·01) 3·40 (·1) 5; and a modification of Gauss's table, in which $\log x$ is the argument, and $\log\left(\frac{x-1}{x+1}\right)$ the tabular result, x going through ·382 (·001) 5 (·01) 3·6 (·1) 5·5. An edition of Von Prasse was published by Halma, at Paris, in 1814; and the last-mentioned table was published separately by Wiedenbach, Copenhagen, (1829).

1834. Robert Wallace, 'Mathematical Calculator,' Glasgow. Six-figure logarithms, with other tables. The trigonometrical tables arranged by double entry for tens and units of minutes.

1836. Anonymous (Simpkin, Marshall, and Co.), 'Logarithmic Tables.' A very neat reprint of Hassler without the (to us) objectionable breaking of the lines in the logarithms of numbers.

1838. G. B. Airy, 'Appendix to the Greenwich Observations, 1837,' London. A table of sines and cosines, with the arguments given in *time*, $0\ (10^s)\ 24^h$ and the signs marked. There is a separate table both of sines and of cosines, each of which is therefore a transformation of the other. And each again is the table from 0 to 6^h repeated, with transformation, four times; so that the pair of tables is an eight-fold repetition of one table. It is to five decimals, without differences.

1839. Anonymous (Taylor and Walton, under Useful Knowledge Society; suggested by Mr. De Morgan; examined by Mr. Farley). *Stereotyped.* A reprint of Lalande (*tirage* of 1831) with a few additions, closely compared with other tables. No error was found in Lalande, and none has hitherto (1861) been found in this reprint. The old numeral type was first completely restored in this work.

After the first *tirage*, the following addition was made:—One page, for example, begins and ends with the numbers 5220 and 5310, and with the logarithms ·71767 and ·72509. According, at the corner of the page, so as to catch the eye on opening the book, is

5220	·71767
5310	·72509

in full. This plan ought to be adopted in all tables, instead of the abbreviations which are frequently employed as headings, unless the plan be adopted which is recommended at the beginning of this article.

1840. Anonymous (Taylor and Walton), Four-figure logarithms on a card. *Stereotyped.* Reprint of a table originally privately circulated among practical astronomers. (See 'Companion to the Almanac' for 1841.)

1842. Sines and tangents to match. Stereotyped.

1840. Farley, 'Six-figure Logarithms,' London. Stereotyped. An excellent table for those who want six figures. The type as in the reprint of Lalande (1839). The whole was suggested by the late Mr. Galloway.

1840. (Second edition.) Moritz Rühlmann, 'Logarithmisch-Trigonometrische . . . Tafeln,' Dresden and Leipzig. Six-decimal logarithms of numbers 0 (1) 10080; logarithmic sines and tangents 0 (1′) 45°; sines and tangents 0 (10′) 45°; arcs and circles.

(1840.) Hülse's edition of Vega. Leipzig, stereotyped. This contains Gauss's tables to five decimals with proportional parts, in six columns, the additional three (which contain a peculiar mode of treating the proportional parts) having been also suggested by Gauss. A more recent tirage of this excellent work, 1846, contains seven-decimal logarithms of numbers 0 (1) 108000; logarithmic sines and tangents 0 (0″·1) 1′ (1″) 1° 32′ and 0 (10″) 6° (1′) 45°; angles to eleven decimals; five-decimal Gauss's tables, A being 0 (·001) 2 (·01) 3·4 (·1) 5; with the proportional parts above alluded to.

1841. Gregory, Woolhouse, and Hann, 'Tables for Nautical Men.' Contains five-figure logarithms, neatly printed; the only instance we know in which five-figure logarithms have proportional parts. There are many astronomical tables.

1841. Riddle, 'Tables,' &c. The six-figure logarithms from Mr. Riddle's well-known work on navigation. *Stereotyped.*

Of the misuse of tables, no instance is more common than that which consists in taking tables of too many places of figures. Four are very often enough, more than five are rarely wanted; but when this happens, tables of seven figures are more conveniently used than those of six, owing to the saving of calculation which is made by the presence of proportional parts. In purely trigonometrical calculations, the advantage of six figures over five sometimes makes itself apparent. It is our own practice, when five figures are suspected to be insufficient, to have recourse to seven at once, which we are satisfied is a saving both of time and thought. For navigation, however, practical opinion seems to set in favour of six figures.

1845. Warnstorff's edition of Schumacher's 'Sammlung von Hülfstafeln' (first published in 1822), Altona. This is a well-known and valuable astronomical collection. What we have here to do with is the republication of Encke's four-figure logarithms, 0 (1) 1000, and 0 (4′) 10° (10′) 45°, and Gauss's logarithms 0 (·01) 1·80 (·1) 4.

1846. R. Sheepshanks, 'Tables for facilitating Astronomical Reductions,' London (also issued two years before, without title, preface, or author's name). This is the most complete *four-figure* table we know of, and will do for the purpose oftener than our orthodox septenarians are aware of. Logarithms 0 (1) 1000, with proportional parts, in decads; logarithms of sines and cosines, *the angle being in time*, 0 (1^m) 24^h, with proportional parts for 10^s, and 0 (10^s) 1^h; table for converting sidereal into mean solar time; logarithmic sines, tangents, and secants 0 (1′) 6° (10′) 45°; constants for precession; tangents and secants 0 (10′) 80° (1′) 86° (1°) 90°; with a rule for the rest; Bessel's refractions; Gauss's tables, thus arranged, log x as an agument gives log $\left(1+\frac{1}{x}\right)$ as a tabular result, and log $\left(1-\frac{1}{x}\right)$ as another, log x being 0 (·001) ·909 (·01) 2 (·1) 4 in the first table, and 0 (·001) 1 (·01) 3 (·1) 4 in the second; log. $\sin^2 \frac{1}{2}$ hour angle, in time 1^h (1^m) 9^h; numbers to logarithms 0 (·001) 1.

1846. G. F. Vega, 'Logarithmisch-Trigonometrisches Handbuch.' Leipsic: edited by J. A. Hülsse; 0 (1) 108000, logarithmic sines and tangents 0 (0″.1) 1′ and 0 (1″) 132, the whole canon 0 (10″) 6° (1′) 45°, all to seven decimals. Gauss's table to five decimals: for A, 0 (·001) 2 (·01) 3·4 (1) 5, with proportional parts.

Among the titles of tables which we might have said something on if we had seen them, collected from different sources, are those of—John Lauremberg, Leyden, 1628, 8vo.; Institutio Mathematica, London, 1661, 12mo.; Strauchius, Witteberg, 1662, 12mo., and Amsterdam, 1700, 8vo.; D. R. Van Merop. Harlingen, 1671; Chr. Grüneberg, Tabulæ Mathem., Berlin and Frankfort, 1690 (oblong form); Chr. Grüneberg, Pandora Mathem., Berlin and Frankfort, 1700, 8vo.; Chr. Wolff, Magdeburg, 1711, 8vo.; J. G. Leibknecht, Giess, 1726, 8vo.; Raph. Levi, Hanover, 1747, 4to., and supplement in 1748; J. C. Nelkenbrechers, Leipzig, 1752, 4to.; J. Melitaõ da Mata, Lisbon, 1790, 8vo. We have a table of which the title is torn out, but at the back is 'Coloniæ, 1649.' We suppose it to be the table which we have seen ascribed to Lubert Middendorff, Cologne, 1648. It is of seven decimals, 0 (1) 10000 and 0 (1′) 45°: and to the logarithms of sines, cosines, and tangents are added the tangents themselves, to three decimals.

1849. Lieut.-Col. Robert Shortrede's 'Logarithmic Tables,' Edinburgh, large 8vo. The whole of these tables were constructed and stereotyped by the labour and at the expense of Colonel (then Captain) Shortrede, of the Bombay army, attached to the trigonometrical survey of India. They first appeared in 1844; but, some defects and errors having been found, the edition of 1844 was cancelled, and a new edition, from corrected plates, issued in 1849. The whole is to seven decimals, and contains: logarithms of numbers 0 (1) 120,000, with differences and their nine multiples; numbers to logarithms ·00000 (·00001) ·99999, with the same; trigonometrical tables *to every second*, with arguments and signs for the four quadrants, both in space and time, and proportional parts. There are also some minor tables. The type is a small even figure, without head or tail, good of its kind, and the same throughout the common and the trigonometrical logarithms. This is, so far as we know, the only set of tables to every second undertaken at the expense of an individual, and it shows extraordinary energy and public spirit.

1849. P. Gray, 'Tables and Formulæ for Life Contingencies,' London. The tables are Gauss's tables, giving log $(1+x)$ where log x is 0 (·0001) 2, and log $(1-x)$ where log x is $\bar{3}$ (·001) $\bar{1}$. The proportional parts are to hundredths.

1849. H. E. Filipowski, 'A Table of Antilogarithms,' London. Five figures of logarithms to seven of number; proportional parts carried to hundredths. Also, Gauss's tables, on a new mode of arrangement.

1850. Hershell E. Filipowski. A table of five-figure logarithms 0 (1) 10000, all on one side of a sheet. The object is effected by help of common figures at the tops of columns; but before we could use the table rapidly, there must be horizontal ruling, and vertical painting of the columns, with regions of different tint to distinguish the logarithms of different second figures. This being done, a person of sharp sight might really have the whole within his grasp without turning a leaf. A common table, with indented margin, as described at the beginning, would find the logarithms far more rapidly. The necessity of dispensing with printed differences is alone almost fatal to the attempt at giving five-figure logarithms on one sheet.

1850. Zacharias Dase, 'Tafel der natürlichen logarithmen,' Vienna. Hyperbolic logarithms to seven decimals 0 (1) 105000, arranged, with proportional parts, in the common way. Mr. Dase is a mental calculator, and, having seen his performances, we think he has more natural power than any of those who have distinguished themselves in this way.

1853. William Shanks, 'Contributions to Mathematics, comprising chiefly the rectification of the Circle to 607 places of tables,' London, 1853. [QUADRATURE OF THE CIRCLE.] Here is a *table*, because it tabulates the results of the subordinate steps of this enormous calculation as far as 527 decimals; the remainder being added as results only during the printing. For instance, one step is the calculation of the reciprocal of 601. 5^{601}; and the result is given. The number of pages required to describe these results is 87. Mr. Shanks has also thrown off, as chips or splinters, the values of the base of Napier's logarithms, and of its logarithms of 2, 3, 5, 10, to 137 decimals; and the value of the modulus ·4342 . . . . to 136 decimals; with the 13th, 25th, 37th, ... up to the 721st powers of 2. These tremendous stretches of calculation—at least we so call them in our day—are useful in several respects: they prove more than the capacity of this or that computer for labour and accuracy; they show that there is in the community an increase of skill and courage. We say in the community: we fully believe that the unequalled turnip which every now and then appears in the newspapers, is a sufficient presumption that the average turnip is growing bigger, and the whole crop heavier. All who know the history of the quadrature are aware that the several increases of numbers of decimals to which π has been carried, have been indications of a general increase in the power to calculate, and in courage to face the labour.

Here is a comparison of two different times. In the day of Cocker, the pupil was directed to perform a common subtraction with a voice-accompaniment of this kind: "7 from 4 I cannot, but add 10, 7 from 14 remains 7; set down 7 and carry 1; 8 and 1 which I carry is 9, 9 from 2 I cannot, &c." We have before us the announcement of the following *table*, undated, as open to inspection at the Crystal Palace, Sydenham, in two diagrams of 7 ft. 2 in. by 6 ft. 6 in. "The figure 9 involved into the 912th power, and antecedent powers or involutions, containing upwards of 73,000 figures. Also, the proofs of the above, containing upwards of 146,000 figures. By Samuel Fancourt, of Mincing Lane, London, and completed by him in the year 1837, at the age of sixteen. N.B. The whole operation performed by simple arithmetic." The young operator calculated by successive squaring the 2nd, 4th, 8th, &c., powers up to the 512th, with proof by division. But 511 multiplications by 9, in the short (or 10—1) way, would have been much easier. The 2nd, 32nd, 64th, 128th, 256th, and 512th powers are given at the back of the announcement.

The powers of 2 have been calculated for many purposes. In vol. ii. of his 'Magia Universalis Naturæ et Artis,' Herbipoli, 1658, 4to, the

Jesuit Gaspar Schott having discovered, on some grounds of theological magic, that the degrees of grace of the Virgin Mary were in number the 256th power of 2, calculated that number. Whether or no his number correctly represented the result he announced, he certainly calculated it rightly, as we find by comparison with Mr. Shanks.

1853. A. Wylie, 'Compendium of Arithmetic,' Shang-hae. A treatise in Chinese, having at the end a table of six-decimal logarithms of numbers 0 (1) 10,000.

1856. J. R. Hind. Natural versed sines . . . . used in computing lunar distances for the 'Nautical Almanac.' This table gives natural and logarithmic versed sines to seven decimals: natural, 0 (10″) 125°, with the proportional parts for each second; logarithmic, 0^h (1^s) 9^h, with the values of the angles in space annexed. This table, though bearing in its title only a limited notion of application, will be exceedingly valuable, especially to those who want sines, cosines, and their squares.

1857. George and Edward Scheutz, 'Specimens of tables calculated, stereomoulded, and printed by machinery,' London. The first production of the machine which two Swedes, father and son, constructed on Mr. Babbage's principles, as suggested by Dr. Lardner's article in the 'Edinburgh Review' (1834), with their own details; five-figure logarithms 0 (1) 10000; with some specimens of other tables. This work was reproduced at Paris, with a French preface, in 1858. In 1859, was published 'Mountain Barometer Tables,' calculated by the same machine.

1859. Edward Sang, 'Five-place logarithms,' 0 (1) 10000.

1860. Ludwig Schrön, 'Schrön's Logarithms,' Tafel I., II., III. We had just, as we thought, put the finishing hand to this article, when the table above-named reached us. Should it turn out to possess the requisite accuracy of printing, it will have decided success. It is a large octavo volume of 550 pages of tables. The type, though without heads and tails, is all as nearly as possible of one thickness, and that thickness not too great, so that it might be called *thin Egyptian;* and it is very legible. The contents are all to seven decimals. Logarithms of numbers 0 (1) 108000, with subsidiary tables at the bottom of the page, which by addition of two logarithms in the page give the logarithms of sines and tangents, 0 (0″·001) 1″ (0″·01) 10″ (0″·1) 1′ 40″ and 1′ 40″ (0″·01) 16′ 40″ (0″·1) 3°. Logarithms of sines and tangents, 0 (10″) 45°. The differences begin to be inserted from 3°; and the first nine multiples complete, that is, one figure more than in the common table of proportional parts, are given in the same page; first for every fifth number, then for every three, &c., as the page will bear it. Under 3° multiples of subsidiary numbers are given, as explained. Then follows a table of proportional parts to complete hundredths, for numbers from 40 to 409.

1860. Galbraith and Haughton, 'Manual of Mathematical Tables.' The usual five-figure table, with Gauss's table, A 0 (·001) 2 (·01) 3·39 (·1) 5. The first British five-figure table, we believe, which gives Gauss's table.

1861. A. De Morgan. Three-figure logarithms: three figures of number to three of logarithm, complete, on a sheet of 7½ by 6 inches. The third figure of the number in every case by the side of the logarithm: all numbers in red, logarithms in black. The *quarter* of a unit in which the logarithm lies, shown by use of the four common punctuating stops. Intended for the earliest instruction in logarithms, and as a substitute for the sliding rule in certain cases.

§ 7. The next tables which we shall mention are those which are wanted in the higher mathematics.

Extensive tables of *elliptic functions* are in Legendre's 'Traité des Fonctions Elliptiques,' 2 vols. 4to., 1825 and 1826. The *factorial* function, Γx, is tabulated in the same work; and also in the 'Exercices du Calcul Integral' of the same author, Paris, 1817, in which several other definite integrals are also tabulated. An abridgment of this table (with ready means of restoring it fully) is in the treatise on the Differential Calculus ('Lib. Use. Know.'), p. 587. Tables of the integer form of Γx, or $1.2.3 \ldots (x-1)$, or rather of the logarithms of the values, are given by C. F. Degen, 'Tabularum Enneas,' Copenhagen, 1824, up to $x = 1201$, to 18 decimal places: this table is reprinted to six decimal places at the end of the article 'Theory of Probabilities' in the Encyclopædia Metropolitana. Tables of the integral $\int \epsilon^{-t^2} dt$ were first given by Kramp, with logarithms of the values, in 'Analyse des Refractions Astronomiques,' Strasburg, 1799. This table is reprinted in the Encyc. Metrop., art. 'Theory of Probabilities.' The form in which this integral more usually occurs in the theory of probabilities (with the factor $2 : \sqrt{\pi}$) was given (by Professor Encke, we believe) in the Berlin 'Astronomisches Jahrbuch' for 1834, from whence it was copied into the article in the Encyc. Metrop., above noticed; and (with extensions) into the 'Essay on Probabilities and Life Contingencies' in the Cabinet Cyclopædia, and into the article on Probability in the new edition of the 'Encyclopædia Britannica.' A few other definite integrals have been tabulated: one very useful one, $\int dx : \log x$, by Soldner, 'Nouvelle Fonction Transcendente,' Münich, 1809, copied into the 'Differential Calculus' ('Lib. Use. Know.'), p. 662. The integrals known by the name of Spence's *Logarithmic Transcendants*, are in the work with that title (Edinburgh, 1809; Sir J. Herschel's edition, London, 1820). There are a few of the integrals in optics scattered through the Memoirs of the Institute and of the Cambridge and Philosophical Society (in memoirs by Fresnel and Mr. Airy). Perhaps we should also mention the tables for the solution of indeterminate equations of the second degree. Of these there is one in Legendre's 'Théorie des Nombres;' another has been given by Jacobi; and a third, by Degen, called 'Canon Pellianus,' Copenhagen, 1817.

There is much need of tables of mathematical results which are not numerical; such as the following, the only ones of which we are able to speak. The first, the well-known collection of indefinite integrals by Meier Hirsch, 'Integral tafeln,' Berlin, 1810, of which an English edition was published in 1823, 8vo. The second, a table of definite integrals, with reference to their sources, by Bierens de Haan, 'Tables d'Intégrales définies,' being the fourth volume of the 'Amsterdam Transactions,' Amsterdam, 1858.

As to astronomical tables, it would be impossible to give any account of the enormous mass which exists or has existed; nor would such an account be of any use, except for astronomical history. They may be divided into two classes: first, the tables of observations published by public or private observatories; secondly, the fundamental tables deduced from observations, to aid in the deduction of future predictions. As to the former, every well-conducted observatory in full work publishes periodically (at intervals of one or two years) its volume of observations, latterly with their reductions. As to the second class, they are not the daily materials of the astronomer, but of the computer of his ephemeris, who supplies the necessary predictions for the current year. In England the Nautical Almanac gives in the preface full references to the tables employed in predicting places, whether of sun, moon, planets, or stars. For general purposes connected with the elements of the solar system, see Baily, 'Astronomical Tables and Formulæ,' London, 1827. The most complete list of the elements of the solar system recently published is at the end of Dr. Mitchel's 'Popular Astronomy' (U.S.), and also of Mr. Tomlinson's English edition of the same work.

The tables in the other physical sciences are mostly collections of facts, and, we believe, generally speaking, by no means so complete as they might be. The value of tabular information seems to be not sufficiently felt. A large portion of every book of chemistry, for instance, is a detailed statement in words at length of facts which might with great advantage be made the components of a table.

§ 8. It remains to speak of commercial tables, a subject of great interest in this country, which has produced a great many. The mathematical tables connected with this subject may be divided into those intended to facilitate calculations of money with regard to other countries, and with regard to transactions in this country; to which we must add, as distinct heads, tables of annuities and other life contingencies, and metrological tables, or tables of weights and measures. Of all these we shall only mention a very few.

The most complete work on foreign exchanges, and on the weights and measures of England, as compared with those of other countries, is 'The Universal Cambist,' &c., London, 1821 (2nd edition), 2 vols. 4to. (with supplements), by the late Dr. Patrick Kelly. We may also mention Tiarks's 'Arbitration of Exchanges,' London, 1817.

Tables of interest of money begin with Stevinus, who in the 'Practique d'Arithmetique,' appended to his Arithmetic, Leyden, 1585, reprinted by Albert Girard in Stevinus's collected works, 1626, gave the first tables of compound interest and annuities. They precede the famous tract 'La Disme,' in which decimal fractions were first proposed. And as this *Practique* should rather have been at the beginning than at the end, if rational arrangement had been studied; and as the 'Disme' again should have preceded it, on the same supposition; we must infer it to be most likely that the tracts were placed in the order in which they were written. If this be the case, then it is pretty certain that these tables of compound interest *suggested decimal fractions*, the account of which speedily follows them. They are constructed as follows:—Ten millions being taken as the base (or *root*, as Stevinus calls it), and a rate, say five per cent., being chosen, the present value of ten millions due at the end of 1, 2, &c., up to 30 years, are put in a column, to the nearest integer. By their sides are the sums of their values, which give the present values of the several annuities of ten million, as follows:—

Table d'Interest de 5 pour 100.

1	9523810	9523810
2	9070295	18594105
3	8638376	27232481
4	8227025	35459506
. . .	. . . .	. . . .
. . .	. . . .	. . . .
30	2313774	153924494

The rates are from 1 to 16 per cent., and also for 1 in 15, 1 in 16, &c., to 1 in 22; or, as the French say, *denier quinze, denier seize*, &c. At the end is a direction to dispense, when convenient, with some of the last figures.

There is thus a virtual use of decimal fractions preceding the formal one. The same thing happens in the tables of Richard Witt, presently mentioned, which we believe to be the first English tables of compound interest, and the first English work (except a translation of the 'Disme' of Stevinus) in which decimals were used: the use of them being something more than the virtual use by Stevinus in the 'Practique.' The next English writer who gave tables of compound interest, Robert Butler, in his 'Scale of Interest,' London, 1633, makes a rather more decided use of these fractions than Witt, and uses the phrase *decimal fractions*, which had then hardly found its way into books. It should be noted that both Witt and Butler give real half-yearly and quarterly tables, as well as yearly ones.

Tables of interest began to be published at the beginning of the 17th century. The earliest we have met with is Richard Witt, 'Arithmeticall Questions,' London, 1613, which, before the introduction of the notation of decimal fractions, gives tables, or *breviats*, containing the significant figures, with rules equivalent to the management of the decimal point; and Clay's 'Briefe, &c., Tables,' London, 1624. In the first half of that century we find in catalogues the works of Fisher, Butler, Webster, and others, with anonymous writers, all containing tables of interest, annuities, or leases. For the tables known by the name of Æcroid, see MORTALITY. The tables of leases, Cambridge, 1686, had the approbation of Newton, as Lucasian professor, and have since been often reprinted and styled Newton's.

Mr. Pocock, in his Bibliography of Annuities, &c. ('Familiar Explanation . . . . of Assurances upon Lives,' London, 1842), gives the following works, which we do not remember to have seen:—'Tables of Leases and Interest . . . ,' London (1628), 12mo.; and William Purser, 'Compound Interest and Annuities, containing the Art of Decimal Arithmetic,' London (1634), 8vo.

In Newton's 'Scale of Interest,' mentioned in the list of logarithms, is a set of tables for six per cent., then the maximum legal rate. There is here what we never met with elsewhere—a common almanac, with months, dominical letters, and fixed saints' days; having, in lieu of astronomical information, simple and compound interest and discount tables, telling for each day the amount of one pound from the beginning of the year, or the present value for the end.

The first edition of Smart's tables, the original of all our large tables of compound interest, is 'Tables of Simple Interest and Discount, at 3, 4, 5, 6, 7, 8, 9, and 10*l.* per cent. per Ann.; also Tables of Compound Interest at the same rates, whereby,' &c. By John Smart, at the Town Clerk's Office, London: London, 1707, 4to (duodecimo size). The second edition, of 1726, is as large, compared with the first, as it is possible its author, "John Smart of Guildhall, Gent.," may have become, compared with the subordinate at the town clerk's office. It adds 2½, 3½, and 4½ per cent. The results are interpolated for half years, which give the tables the appearance of being calculated for interest payable half-yearly; but the fact is that yearly payments are supposed. A second edition of this work, enlarged, by C. Brand, London, 1780, has the reputation of containing many errors. The first edition (which we did not know of when we first wrote, and we find all * modern writers knew as little), besides a smaller range of rates, has not the half-years, and has only six decimal places. The tables of simple interest are also of very little extent. This set of tables was incorporated (with acknowledgment) in the article 'Interest' in the second volume of Harris's 'Lexicon Technicum,' London, 1710. There was an abridged edition, with some of the rates and of the half-years left out, but still to eight figures, 'Tables of Interest, &c., abridged for the use of Schools, in order to instruct young gentlemen in the use of Decimal Fractions,' by John Smart, &c., London, 1736, quarto (octavo size).

Mr. Baily's 'Doctrine of Interest and Annuities,' London, 1808, is as extensive as Smart's for whole years, and as correct; and the 'Tables of Leases,' London, 1807, by the same author, contain the simple cases which the name implies, tabulated by themselves. The 'Doctrine of Interest,' by Francis Corbaux, London, 1825, contains the real distinction of yearly, half-yearly, and quarterly interest: these tables are repeated in the same author's work on 'Population,' London, 1833. Mr. Hardy's 'Doctrine of Simple and Compound Interest,' London, 1839, contains rates of interest increasing by ¼ per cent. from ¼ up to 5 per cent., with succeeding integer rates. All the standard works on life annuities contain tables of compound interest.

There seems to have been a tendency at the beginning of the last century to publish commercial tables in copper-plate, probably with a view to secure the advantage which stereotype has since secured in a better form. Thus we have the "arithmeticall tables" of C. Bardon (Roy. Soc. library) without date; Lostau's 'Manual Mercantile,' second book (first never published), London, 1733; Rev. G. Brown's 'Arithmetica Infinita, London, 1717; the two last being multiplication tables, with multiples of numbers and fractions useful in money transactions, arranged under heads. The following may be mentioned as containing hints which might even now be useful:—Benjamin Webb, 'Tables for Buying and Selling Stocks,' London, 1759; also 'The Complete Annuitant, or Tables of Interest,' London, 1762; Hayes's 'Moneyed Man's Guide,' a table for computing dividends, London, 1726. The French have a large number of tables answering to our ready-reckoners, under the names of *Barême* (a word of the same use with them as Cocker with us), *comptes-faits*, &c. We have seen one of them of the decimal character, in which a metal plate with rectangles pierced in it serves, on one rectangle being placed over the integers of the number given, to make another separate those of the number to be found.

Commercial tables of any real power are rendered impossible in practice by the use of shillings, pence, and farthings, except by an extent of matter which makes them very expensive. If, indeed, the rule for decimalising the parts of a pound [COMPUTATION] were well learned and properly used, some of the older tables, which have fallen entirely into oblivion, would certainly be revived with effect. Two of those presently mentioned will certainly be reprinted when the time comes; Brown's 'Arithmetica Infinita,' and Webb's 'Tables for Buying and Selling Stocks.' The main part of the former is the first nine multiples of the decimal, which expresses any number of farthings in a pound. Thus, under 7*s.* 8½*d.* are ·3854166 . . . and its multiples up to nine times. The latter has the multiples necessary to find the quantity of stock which answers to any sum of money, and *vice versâ*, at different prices. These are both pocket tables, and their places are supplied at present by works of much greater bulk and less extensive use.

We now give a very condensed account of a few mercantile tables. We take them merely because we happen to have examined them, without any selection. Such a list, meagre as it is, both in amount of works and in description, may be of much use to one who is contemplating the construction of a table. He may be warned that tables exist which he should consult before he settles his plan; for those we have quoted may suggest the expediency of looking out either for themselves or for others resembling them; or he may receive a hint even from so brief a description as ours. There will appear, in so short a list as this, sufficient evidence of the never-ceasing attempt to bring decimal * fractions into tabular connection with our mixed money. There has never been any lasting success with the world at large; and we must continue, in our commercial arithmetic, at perpetual war with our own first principles, until we are wise enough to decimalise our coinage, and ultimately our weights and measures.

In the following list, the letters Q., O., or D., for quarto, octavo, and duodecimo or under (referring to size, and not to mode of printing), precede the date and begin the description of each work:—

O. 1613, London: Richard Witt, 'Arithmeticall Questions;' compound interest. Q. 1619, Leipsic: 'Ein newes metzbar gerechnetes Rechenbuch;' ready-reckoner, tables of multiplication of prices. D. 1629, London (2nd edition, many editions): William Webster, 'Webster's Tables;' small tables of simple interest. D. 1632, London: John Bill, 'Accompts cast up;' ready-reckoner, simple multiplication of integer numbers up to 100 times; the earliest English ready-reckoner we know of. O. 1633, London: Robert Butler, 'The Scale of Interest;' tables of discount and present value. O. 1668, London: John Newton, 'The Scale of Interest' (see Logarithms, 1668). O. 1677, London: Michael Dary, 'Interest Epitomized;' small tables of compound interest; a rare and remarkable book in other respects. D. 1682, Amsterdam: J. Sarfatti Pina, 'De Lichtende Koopman's Fackel;' multiples of money in facilitation of exchanges. D. 1686, Cambridge [Mabbot]: 'Tables for Renewing and Purchasing of the Leases of Cathedral Churches † and Colleges;' reprinted almost down to our own time (to 1808 at least) under the name of Newton, because it has Newton's certificate of approbation of the method. Mr. Edleston, who has found the name of the writer in his researches into Newton's biography, says that he was manciple, a caterer, of King's College. In the treasury of Trinity College, he adds, is a table and explanation, in Newton's handwriting (1674-5), of the fines for renewing years lapsed in a lease for 20 years. It is entitled, 'Tabula redemptionalis ad reditus Collegii SS. Trinitatis accomodata,' and gives seven years' purchase for the whole lease, and one year for seven years lapsed. This allows the lessee upwards of 13 per cent. This table was employed till 1700, when Bentley introduced 10 per cent. tables; but the "greediness for present sealing money" compelled a return to the old system. Dr. Smith, in 1742, reintroduced the 10 per cent. tables, which became 9 per cent. in 1750. Newton's table is published in the 'Journal of the Institute of Actuaries' for January, 1861, vol. ix., No. 42. O. 1693, London: W. Leybourn, 'Panarithmologia . . . . all performed by tables ready cast up;' ready-reckoner, multiples of prices, &c. D. 1707, London: John Smart, 'Tables of Simple Interest . . . . also Tables of Compound Interest;' the first edition of these celebrated tables. D. 1710, London: John Castaing, 'An Interest Book . . . ;' interest per year reduced to days by tables. O. 1711, London: E. Hatton, 'An Index to Interest;' units, tens, and hundreds of pounds principal, reduced to interest for each number of days in the year. D. 1718, ——: Geo. Brown, 'Arithmetica Infinita;' all farthings under one pound reduced to decimals, with the first nine multiples of each (the whole in copper-plate; the figures very rough, as if put in by the author's own hand). Q. 1726, London: John Smart, 'Tables of Interest, Discount, Annuities;' the second edition, and the best. D. 1726, London: Richard Hayes, 'The Money'd Man's Guide;' tables of dividends on sums proceeding by eighths of a pound, at — per cent.

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* Dr. Farr ('Reg.-Gen. Rep.,' 1844, p. 559) mentions the edition of 1726 as the *second* edition.

* The day after we had written this we came in contact with an extract from the 'Publishers' Circular,' as follows:—"An old copy of Langham's 'Nett Duties and Drawbacks,' digested into an easy method, once the standard authority on the subject, gives us the exact state of the case a hundred years ago, and leaves us in some astonishment that any head, native or foreign, could have mastered the complicated details then necessary for their own safety to be known to importers . . . . Decimals, indeed, appear to have been the delight of the tariff-maker of old, for the charge on every one of the fifty-eight items [of paper] concludes with some such a fraction—occasionally reaching the delicate nicety of 92⅝ hundredths of a penny." This merely means that commercial arithmetic is more of a mere routine than it was, and that a hundred years ago decimal fractions were more cultivated than they are now.

† Later editions of this work are accompanied by a letter on the value of church leases, which was one commencement of a long dispute, giving many pamphlets. (See 'Notes and Queries,' 2nd series, vol. iv., p. 361.) The practice of raising the fines, which had been very much too low, had been growing for some thirty years previously to 1686; and the publication of these tables seems to have been in justification of the rise. Hence the importance attached to obtaining from Newton a certificate of the method, which those interested might have denied. The dispute, which never died, was very warm in 1729–31, when the clergy were threatened with legislative interference, and did actually receive some implied recommendations to desist from the House of Commons. Common sense, however, seems to have found out at last that the clergy, in spite of the augmentations, were making much less of their lands than the laity; and the next phase of this history is that of 1837, in which year the poor divines were threatened by parliament with the loss of the management of their estates, for letting them *too low*. It is not easy to please everybody.

D. 1735, London: Gael Morris, 'Tables for Renewing and Purchasing Leases . . .;' and, with another title-page, tables of simple interest for years, months, and days. O. 1735, London: James Lostau, 'The Manual Mercantile—Second Book;' the first never published. This book is 450 pages of copper-plate; the descriptions, &c., in a professional handwriting; all the table-work in the roughest figure, as if put in by the author for security against error. First nine multiples of numbers up to 1609; reciprocals to seven significants, and first nine multiples, up to 1535; numbers advancing by eighths of a unit, and their nine multiples in decimals from 100 to 140, and then by fourths to 156; reciprocals of the same, with nine multiples; pence and farthings in decimals of a pound, with eight and afterwards seven significants, with nine multiples, up to 140*d.*; the number of times pence and eighths are contained in a pound, in decimals, with first nine multiples, up to 140*d.*; a mass of tables for exchange, commission, reduction of weights and measures, &c. &c., all, or most, having results expressed in decimals, with nine multiples of each. O. 1736, London: John Smart, 'Tables of Interest;' the large tables abridged into a school-book. O. 1756, London (19th edition): John Playford, 'Vade mecum;' ready-reckoner of the modern type. O. 1756, London: ——, 'New Sett of Interest Tables;' small tables, followed by tables of excise on beer and ale, printed on one side only, apparently to allow pasting on a wall, and 'designed for a check on the custom-house and excise officers.'

D. 1759, London: Benj. Webb, 'Tables for buying and selling Stocks;' the chief table is one of numbers increasing by eighths, given in decimals, with nine multiples to each, from 60 to 130; and their reciprocals in the same way. D. 1762, London: Benj. Webb, 'Complete Annuitant;' collection of tables subsidiary to interest, not easy to describe briefly. D. 1766, London (14th ed.; 16th in 1775): Richard Hayes, 'Interest at one view;' interest in the form of the ready-reckoner for months and days. O. 1773, Amsterdam: Nicolas Barreme, 'Comptes-Faits;' an edition of the celebrated French ready-reckoner, which, like ours, consists of multiples of sums of money. The name of Barreme (so spelt in the licence, though now *Barême*) is ingrafted on the French language as a word for mercantile calculation. Our *Cocker*[*] is a jesting allusion; but *Barême* is quite a serious word. O. 1773, Brussels, René Neron, 'Comptes-faits[†] pour les changes;' exchanges between different countries, in the ready-reckoner form. O. 1798, Paris: Blavier, 'Nouveau Barême;' adapted to the change of coinage. Q. 1799, London: John Wilson, 'Tables to facilitate the computation of Interest;' containing the proportion of ·05 for each number of days in the year, with multiples of each fraction up to 100, to nine decimals. All calculations are made for five per cent., and afterwards reduced to the rate given: a very common principle of tables. O. 1804, London: S. Newman, 'Collection of Mercantile Tables;' the ready-reckoner (or *multiple*) principle adapted to prices, lengths, interest, &c. O. 1807, London: Francis Baily, 'Tables for . . . Leases' (second edition; first in 1802): the first separate[*] tables of leases of the modern form. Q. 1808, London: F. Baily, 'The Doctrine of Interest and Annuities;' a well-known work, the tables from Smart. D. 1811, London: Wm. Inwood, 'Tables for . . . Estates . . . and Leases;' the idea, and some of the tables, from Baily. O. 1816, Calcutta: G. M. Anderson, 'The Universal Calculator;' a large ready-reckoner for prices, exchanges, interest, weights and measures, &c. O. 1825, London: Fr. Corbaux, 'The Doctrine of Compound Interest;' tables, with a large introduction of half and quarter rates of interest; the tables are added to the author's work on population, 1833, 8vo. O. 1839, London: Peter Hardy, 'Doctrine of Simple and Compound Interest;' tables, with half and quarter rates of interest. O. 1841, London: Geo. Reid, 'Tables of Exchange;' in the ready-reckoner form, relating entirely to sterling and dollars. D. 1847, London: David Allester, 'Table of Simple Interest, comprised in one page;' this page has an arrangement by which each day is shown at five per cent., with its nine multiples. O. 1847, London: D. Allester, 'Decimal Dividend Tables;' the basis consisting of shillings and pence in decimals of a pound, with the hundred multiples of each. O. 1849, London: James Laurie, 'The Golden Ready-Reckoner;' ready-reckoner by multiples of one share at pounds and sixteenths per share. O. 1857, London: C. M. Willich, 'Interest and Time Commutation Tables;' conversion of five per cent. into any other practical rate by inspection; and conversion of days to run into days which give the same at five per cent. D. 1859, Edinburgh: W. Waterston, 'Manual of Commerce' (2nd edition); a ready-reckoner, combined with interest, dividend, &c., tables, and information of many kinds. O. 1859, London: Feodor Thoman, 'Theory of Compound Interest;' a new disposition of the subject, the tables being the logarithms of amounts, and the logarithms of annuities which one pound will purchase. D. 1859, Halifax: 'Nicholson's Ready-Reckoner;' a good specimen of a class of sixpenny books which are now common.

We cannot pretend to give a technical list of life assurance and annuity tables: anything we could do in this way, in any space we could give, would be professionally useless, and otherwise worse than uninstructive. We may, however, attempt to point out and to illustrate an epoch of activity which commenced about the year 1840, and which still continues. In the year 1838, the chief of the professional tables were in the well-known works of Price, Morgan, Baily, Milne, Griffith Davies, and Finlaison. The extent of tables, as judged practicable, went as far as annuities on two lives, for all ages differing by multiples of five years, at 3, 4, 5, and 6 per cent. Barrett's method, the greatest augmentation of resources which was ever created on this subject by any one person, was not in use for want of sufficient application to acknowledged rates of mortality. Milne's book best represents the laborious character of many computations which are now either reduced to insignificance, or themselves actually tabulated for reference. This valuable work (1815) was published by the author at his own expense, and with a certainty of heavy loss; and no public acknowledgment of his merit was made, even when it had become apparent that he had changed the basis of life-tables, and introduced an important reformation by the only efficient means—the construction of a body of tables competing in extent with those already in use, and beyond challenge as to accuracy of computation. Barrett's method is not[†] noticed by Milne in this work; but it only appeared in Baily's Appendix of 1813, and Milne could hardly have had time, occupied as he must have been with his own work, to have thoroughly examined it, much less seriously contemplated the use of it.

The impulse was given by the Useful Knowledge Society (who however had a colleague, as we shall see), when they brought forward Mr. David Jones, and recommended, almost insisted on, a very[‡] considerable extension of his original plan. The only tables in existence for every combination of two lives had been published by Mr. McKean, in 1837, giving on one large sheet the rates 3, 4, 5, 6 per cent., by interpolation from the Carlisle tables. Mr. Jones (whose work was completed in 1843) gave every combination for 3, 3½, 4, 4½, 5, 6 per cent., both in the annuities, and in Barrett's subsidiary tables; that is, twelve tables for all combinations, instead of four tables[*] for combinations differing by multiples of five years of age: and this far from all. A short account of some of the tables since published will show that the example has been vigorously followed; both as to the completion of things which had been but partially done, and as to the origination of new undertakings.

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[*] We have endeavoured to find the reason why *Cocker*, or rather the book which Hawkins put out in Cocker's name, should be selected as the type of commercial arithmetic. We trace the allusion to 1756, and no farther back. In that year Arthur Murphy's farce of 'The Apprentice' appeared, in which the old merchant *Wingate* is perpetually eulogising *Cocker's* arithmetic. Wingate and Cocker were two of the best-known books on arithmetic. If the allusion cannot be carried farther back, then the probability will be that Murphy took the names of the arithmeticians with whom he most often came in contact, and used them as described. In that case Wingate would have been our Cocker, if Murphy had chosen to make Cocker his Wingate; and Wingate much better deserved the distinction.

[†] Dedicated to the Duke of Lorraine, in verse, which ends as follows:—

> Grand Prince, sois propice à ma juste demande,
> De mon petit travail daigne accepter l'offrande,
> Et, quittant d'Apollon le stile familier,
> Permét-moi de me dire en stile régulier
> Monseigneur,
> De vôtre Altesse Royale,
> Le très-humble, très-obeissant,
> et très-respectueux Serviteur,
> NERON.

[*] A case arose out of this work which illustrates the varying decisions which prevail in the courts when a single judge decides questions of fact. Baily applied for an injunction against a work in which he held his own work to have been pirated. He produced his own original calculations; and proved that all the misprints and errors of the last figure, by the score, which occurred in the parts of his work in question, occurred also in the alleged piracy. But he could not satisfy the court that a piracy had been committed: he happened to light upon a judge who would have thought it might have been a coincidence, if he had seen his own name growing in mustard and cress. Persons who have reason to fear that their tables will be pirated should lay some special traps for detection: many might easily be suggested.

[†] Milne has made it apparent, in his work, that he had had some difference with Baily, who is not alluded to by name, but only by such phrases as "the last author who has treated on this subject." There certainly had been some disagreement. The Sun Fire Office became also a life office in 1810, and Baily was then consulted by the directors: we suspect that the disagreement, whatever it was, then took place. But by the time Milne published his article on annuities in the Encyclopædia Metropolitana (of which the private copies are dated 1837) much of this feeling had worn off. Baily's name is mentioned, and his merits are judiciously, though coldly, acknowledged: but Milne was not given to strong praise; he neither blew his own trumpet, nor that of anybody else. Of Barrett's method Milne thought highly. Having more than once heard it suspected that he was averse to its use, we give an extract from a letter of his to the writer of this article, dated Nov. 17, 1841, while Jones's work was in progress of publication in numbers. "Many thanks . . . . for the Companion to the Almanac of the Useful Knowledge Society, to which truly useful society we are also indebted for Mr. Jones's tables, which will greatly facilitate calculations."

[‡] We speak from positive knowledge. Mr. Jones, though no way disinclined

In saying that the Useful Knowledge Society first showed the way, in actual print, to the construction of more extensive tables, we should commit great injustice to a most daring and persevering calculator, if we omitted to notice that Mr. Edward Sang could have received no hint from their proceedings. His 'Assurance and Annuity Tables,' Edinburgh, 1841, large folio, give, for one life and 3 per cent., almost every deduction from the Carlisle tables which an actuary could have supposed possible to be wanted. And Mr. Sang worked with his hands[†] as well as with his head. Over and above a table of five-decimal logarithms and antilogarithms, every result in the book has its logarithm attached to it. And with this we have the present values of every annuity and assurance, temporary or deferred, which can be made on one life, at any age, and for any duration or deferment: together with a mass of values and premiums for other cases which we shall not attempt to specify. In 1859, Mr. Sang published a second volume, containing, also for 3 per cent., a body of results on two lives which meet all the actuaries' cases; also with logarithms attached. The offices, and many of the actuaries, were at first inclined to look very coldly upon these magnificent efforts; but, so far as we have observed, we think there is now a disposition to acknowledge their utility: their merit was never denied.

Mr. Jones and Mr. Sang, independently of each other, showed that there was no occasion to be frightened at the notion of *calculating and printing* all the cases of a problem of two lives, or of one life for terms of years: at the time when they began their labours, a routine had been established by the consent of several distinguished writers, which consent caused ordinary calculators to look upon anything beyond the routine as next to impracticable. In 1848, Mr. T. Wigglesworth, in 'Carlisle Probability-Tables of the Logarithms . . . .' London, 8vo., gave the logarithm of the chance of surviving every number of years, at every age, from the Carlisle tables. In 1850, Mr. W. Orchard, in 'Single and Annual Assurance Premiums,' London, 8vo., gave tables for converting the value of an annuity into the single or the annual premium for a corresponding assurance; the necessity for which often arrives in masses of instances together. The rates are 2½, 3, 3½, 4, 4½, 5, 6, and 7 per cent.

In 1850, Mr. H. E. Filipowski, in an appendix to his work on antilogarithms, London, 8vo., gave Carlisle annuities at 3 per cent., for *three* joint lives, for all combinations of quinquennial ages. This is the first table of three lives: nothing more than specimens had been previously published.

In 1851, Messrs. P. Gray, H. A. Smith, and W. Orchard, in 'Assurance and Annuity Tables,' London, 8vo., gave, for the Carlisle tables, at 3 per cent., the premium and the annual premium for every case of survivorship assurance on two lives. In 1850, Mr. W. T. Thomson, of the (Scotch) Standard Life Assurance Company, published, in fifteen[‡] sheets, meant to be joined in one, what we may describe as, for the Carlisle tables at 3 per cent., a collection of Barrett's tables, one for each age in the tables: or the number living at every age of life discounted to every lower age. This table might have had its use, if Mr. Thomson himself had not superseded it, in 1858, by his *book*, entitled 'Actuarial Tables, Carlisle Three per cent.,' Edinburgh, 8vo., giving the ultimate elements of the old form of calculation: that is, the present value and logarithm of every year of annuity, and the logarithm of the risk of death in each year, from and after every age. These values are put together in successive sums so that the present value of every deferred annuity, and of every deferred and temporary assurance, is gained directly from the table. A complete table of probabilities of living, logarithms and primitives both, is also given; with some other tables. In 1858, Mr. David Chisholm, in 'Commutation[*] Tables for Joint Annuities and Survivorship Assurances, based on the Carlisle tables at 3, 3½, 4, 5, and 6 per cent.,' London, 2 vols., 8vo., introduced, in addition to Barrett's tables for two joint lives, the form for survivorship assurances, by which such assurances for terms of years, or when deferred, are immediately calculated. There are other efforts with which we are not acquainted: from those which we have cited, the reader may see the very great progress which the actuary's tables have made in the last twenty years.

We shall mention a literary curiosity of the subject, the spurious edition of Francis Baily's celebrated work[†] on Life Assurance: the only instance in modern times, we believe, in which a heavy work of algebra and tables has been *counterfeited*. The genuine work, though never out of reputation, was soon out of print: and such copies as were sold by auction fetched enormous prices. About the year 1850, copies of the work, in appearance, were offered at the assurance offices at less than a quarter of the old auction prices: which were discovered on examination to be spurious. The type, paper, &c., of the genuine work had been imitated almost to the smallest points; but the careful supervision which Baily always gave to details, and the excellent performance of his printer, could not be imitated. Those who do not know the original edition will immediately detect the spurious edition by an inverted δ being always used for the letter ρ. Shabby as the undertaking was, it invaded no copyright: and as no one now much wants Baily's work for the *tables*, so that it matters less whether these be accurately reprinted or not, it must be granted that the still valuable part of Baily's work has been made more accessible, and therefore more useful. We are of opinion that an edition of the work, with no more than specimens of the tables, and notes, critical, historical, and prospective, would command circulation.

The railroads have created a demand for tables of the cubic yards in cuttings, embankments, &c. Of these we select three, of extreme and mean sizes. First, 'A general sheet-table, &c.,' on one side of one sheet, by F. Bashforth, M.A., very efficient for its size. Secondly, 'Tables for . . . . earthwork of Railways,' 1847, by C. K. Sibley and W. Rutherford; a collection of sheets, with flexible cover, small folio. Thirdly, the second edition, 'Tables for facilitating the calculation of earthwork,' by Sir John Macneill, Dublin, 1846, an 8vo. volume of 368 pages. We describe what we have by us, not knowing what editions may now be current, or what other works there may be.

The practice of stereotyping tables is one which should be strongly enforced, if it were not that publishers seem now to be aware of its importance. A second edition derives no authority from the goodness of the first, because the printer, who is, as already observed, as important a person as the author in the matter of tables, has again stepped between the latter and the public. In reading the proofs of important tables, it is desirable that three persons should be employed, one to read from the manuscript, the others to watch two separate proofs, without communication with each other, as done in the Nautical Almanac office. The strictest investigation should take place in the proof which is taken from the stereotype, ordinary pains being taken with the previous proofs. Persons who have to correct the proofs of tables alone should bring the manuscript as near as possible to the proof by folding it conveniently: even if the folds were altered after every two or three lines, so as always to have both manuscript and proof under the eye in one position, it would not give more trouble than would be well repaid. Double figures should be particularly attended to; no mistake is so likely to be made, either by the compositor or the reader, as 744 for 774, and the like. This, and misplacing the order of the figures, as 012 for 102, are the things which it is most difficult to avoid. Again, of the two things under examination, manuscript and proof, the more difficult one should be looked at first, for the mind is apt to allow knowledge derived from the more easy to give help in interpreting the more difficult. Thus, if the type be harder to read than the manuscript (a very common thing with thick even-sized numerals), make out the proof first, and then look at the manuscript; and *vice versâ*. If two readings be given, vary the mode; the following may for instance be the plan adopted: if the manuscript column contain *a*, *b*, *c*, &c., and the printed column A, B, C, &c., look at *a*, compare it with A, then at B, compare it with *b*,

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to the undertaking, would not have ventured to propose such an unheard-of extent of tables; and this extent was proposed to him, and not by him, during the actual progress of the work. It was Mr. Jones who first proposed a large extension of existing means, and the Society asked for more.

[*] In our first article appears the following: "The work of Mr. Jones on *Life Annuities*, in the 'Library of Useful Knowledge,' which is now brought nearly to a close, contains more tables than the old standard works all put together, and is the first in which extensive tables for what is called *Barrett's Method* are furnished, both for one and two lives."

[†] Mr. Sang arranged the types in the boxes, before using them, with all the care of composition, and set them up in the boxes all in one way. He then set the types for printing from with his own hands. The second volume was treated in the same way by his computers. A computer can set up the types from the original calculations; and thus the labour and risk of re-writing are avoided. The time of setting up was ultimately reduced to not much more than what would have been required for re-writing the manuscript; the computers, after very little practice, were able to outstrip the speed of ordinary compositors. The only predecessor of Mr. Sang in this matter that we know of is Mœstlinus, who, in 1596, while superintending some printing for Kepler, writes that the tables have been very badly described (as to structure), and adds, *Hinc nullus typothetarum operi manus admovere potest: Ipse cogor typothetam agere.*

[‡] This form is impracticable. The fifteen sheets joined together make a table of 9½ feet by 4¾ feet. This is too much, even for the wall of an office. We examined the table by nailing the sheets against the front of a bookcase, and using a step-ladder, as Gulliver did when pursuing his studies at Brobdingnag.

[*] The tables formed on Barrett's method are variously described as *Barrett's* tables, *Davies's* tables (G. Davies was an improver), *D and N* tables, and *Commutation* tables.

[†] In 1848–9, something more than a dozen copies of Baily's work came into the hands of Mr. Maynard, mathematical bookseller, slightly imperfect. The missing parts were reprinted (pp. 305–320 and 545–552). These copies were in Baily's hands till his death: and when the book was selling by auction at and over five guineas, his friends applied to him again and again to have the deficiencies made good and the books put into circulation; but they never could prevail.

then at *c*, compare it with C, and so on; the order of inspection being *a*A, B*b*, *c*C, D*d*, &c. Some persons examine best by the eye alone, others by the ear also, repeating aloud. Each one must ascertain for himself which practice is best for him; but whatever it may be, it should be varied. Alteration of position, motion of the hand or foot occasionally to mark the transitions, change of the tone of repeating, &c., are useful: it is hardly credible, to those who have not tried, how much the perceptions are dulled by the monotonous comparison of one column of figures with another, or how many and how gross errors both eye and ear, when tired, will suffer to pass. Persons who are not much used to this labour might very well proceed as follows. Let them request the printer to make, at his own discretion, a certain number, say three, of mistakes (author-traps) in every page, carefully registering them, but not on the manuscript. The author may then be certain that he ought to detect three mistakes in every page, and will know that he has been careless if he have not that number at least. But at the same time, an author who has not reason for confidence in himself, may very safely leave good manuscript tables entirely to the printer, if he make the latter understand that he does not intend to correct till all is printed off, and will require every page containing an error to be cancelled. No good printer would now refuse to engage to furnish a fac-simile of a manuscript, on the simple condition of being allowed to refer to the author for decision as to any doubtful word or figure in the writing; and the accuracy with which the first-rate London[*] printers turn out their proofs, even where the manuscript is criminally bad, is surprising. We have frequently looked at page after page of table-matter more times than we should otherwise have thought necessary, merely because the total absence of detected error left it an unsettled point whether it was the excellence of the proof, or a temporary suspension of our own quickness of perception, which caused the absence in question.

Catalogues of tables (separate) may be seen in the catalogue of the Royal Society's Library; in Murhard's 'Bibl. Math.;' in Lalande's 'Bibl. Astron.' (in virtue of the index); but there is nothing approaching to even a moderately perfect catalogue.

* * *

In the preceding article we have described, we believe, all the tables of note, whether in history or practice, so far as general tables of pure mathematics are concerned. We have omitted those which relate only to astronomy, life contingencies, or any other special application of mathematics. As the article stood in the 'Penny Cyclopædia,' we had brought forward about 318 tables, of which 221 had been taken from actual inspection, and the remainder from various authorities, very few indeed from one only. In Lalande's 'Bibliographie Astronomique' there are 208 tables mentioned, *including astronomical ones.* In the printed catalogue of the Royal Society's Library the entries under tables, of every sort, mathematics, astronomy, navigation, geography, meteorology, &c., are 536 in number, including from the merest tide-table for one year up to the largest body of logarithms. And upon looking at the appearances which the different catalogues present, we do not find one in which 200, or even 100, tables of pure mathematics are mentioned as having undergone the actual inspection of the compiler. In the present article we have given about 457 tables, of which 332 are from actual inspection. It would not, then, we suspect, be a very extensive undertaking to make as complete a list of tables of all kinds as can now be recovered; and the undertaker of it might expect to be able to verify about two out of three from inspection.

In the present article some additions have been made, both of tables and of facts alluding to tables already inserted, and several corrections. We have not made any effort to include all the tables of the last few years, preferring to direct our chief attention to the improvement of the antiquarian part of our task. To this end we have examined anew all the old tables which we could conveniently see. In reviewing our work, we find that we have sometimes spoken of the *decimal places* in a table, and sometimes of the *radius* to which it is constructed; but we do not mean that the old tables had decimal places, properly so called. We must also remind the reader that this article is not *bibliographical;* our affair is not with books as books, but with tables as tables. Accordingly, the descriptions of books are not fully given: and their contents, except so far as they are the tables spoken of, are wholly unnoticed.

TABLE, ROUND. The most famous Round Table is that of King Arthur, which is said in the old romances to have been constructed by the wizard Merlin for Uther Pendragon, Arthur's father, from whom it passed into the possession of Leodigan, or Leodegrance, king of Camelard, or Carmalide, whose capital was Carshaise, and then came to Arthur as the portion of his wife Guenevre, daughter of that monarch. The romance of the 'Mort d'Arthur' says that Merlin made it "in token of the roundness of the world;" according to the metrical romance of Merlin, it was made in imitation of one which had been set up by Joseph of Arimathea in commemoration of that at which the twelve apostles ate the last supper with their divine Master. The Round Table is not mentioned at all by Geoffrey of Monmouth, either in his 'Chronicle,' or in his 'Life of Merlin' in Latin verse; but it is noticed by his contemporary Wace, in his metrical 'Roman de Rois d'Angleterre.' The Round Table was intended, to quote the analysis of the romance of Merlin given by Ellis ('Specimens of Early English Romances,' i.), "to assemble the best knights in the world." There are different accounts of the number of the Knights of the Round Table, which indeed appears not to have been always the same. The romance of Merlin, which states that Uther had no power to fill all the seats, makes that king nevertheless to have nominated 250 knights, and these are also spoken of as forming the number of the order under Leodegrance. The 'Mort d'Arthur' makes Leodegrance say, in surrendering it to Arthur, "I shall give him the Table Round, the which Uther Pendragon gave me, and when it is full complete, there is a hundred knights and fifty; and, as for an hundred good knights, I have myself, but I lack fifty, for so many have been slain in my days." Of the fifty knights that were wanted, Merlin was at the moment only able to find twenty-eight for Arthur; but some were added afterwards. Other accounts again make the complete number under Arthur to have been only a hundred.

It is asserted by some of the chroniclers that some time before Edward III. instituted the order of the Garter, he established in the castle of Windsor a fraternity of twenty-four knights, and erected for them a round table, in imitation of that of Arthur, with a chamber in which it was placed, in what is yet known as the Round Tower. Bishop Percy, in his 'Reliques of Antient English Poetry,' remarks "that the round table was not peculiar to the reign of King Arthur, but was common in all the ages of chivalry. The proclaiming a great tournament (probably with some peculiar solemnities) was called holding a Round Table." And he quotes a passage from Dugdale, in which that learned antiquary, describing a tournament held at Kenilworth by Roger de Mortimer, in the reign of Edward I., says, "Then began the Round Table, so called by reason that the place wherein they practised those feats was environed with a strong wall made in a round form." Percy adds that Matthew Paris frequently calls jousts and tournaments *Hastiludia Mensæ Rotundæ.* These round tables were probably a contrivance on the principle of the modern Round Robin, to prevent any dispute about precedency. There are several circular elevations in different parts of England which are still called Arthur's Round Tables.

TABLES, TWELVE. [TWELVE TABLES.]

TACK is the technical term in Scotland for a lease, whether of lands or edifices; the rent is called the tack-duty, and the tenant the tacksman. The Scotch lease, however long its duration, is purely a contract, and does not partake—at least in questions between landlord and tenant—of the peculiarities of the feudal system. In early times it is possible to trace something like an inferior system of vassalage in the nature of the agriculturist's tenure; but as all descriptions of permanent estates could be constituted in the land by the adaptation of the feudal usages, there was no temptation to convert the contract for the limited occupation and use of the land into a means of constituting a semi-proprietary right in it. The system of leases accordingly, as one of mere letting and hiring, took its principles from the Roman contract of *locatio conductio*, the right of the lessee or tacksman being so purely personal that it was ineffectual against a party acquiring the lands by purchase from the lessor. Leasehold rights, however, in questions of succession, and in the form of attachment, employable by creditors, have by usage come into the position of real or heritable property, and may now be registered and transferred by the appropriate forms of transfer like estates in fee simple.

Writing is necessary to constitute a lease, although possession during the part that may remain over a year begun, may be held as a right from sufferance and acquiescence in its commencement. Without writing the term is for a year only.

TACKING. The evolutions of a ship when contending with an adverse wind are called tacking; and the course upon which a ship lies is called its "tack," and whether the wind blow on the starboard- or port-side, these are called starboard or port tacks. In endeavouring to move a ship under sail towards the point from which the wind blows, she must necessarily be close hauled, that is, her sails must be so braced as to enable her to proceed as near the wind as possible.

We may illustrate the operation of tacking by reference to a similar movement in ourselves, whether on foot or horseback, when we mount a steep incline on shore; for, instead of facing the inclination of the hill in its abruptness, we sidle along upwards in a zig-zag direction until the summit is reached,—and thus it is with tacking at sea; where, however, we use horizontal angles instead of the vertical ones on land.

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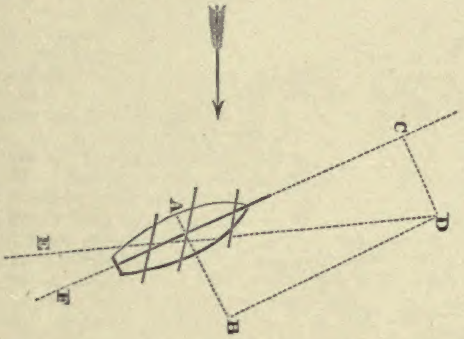
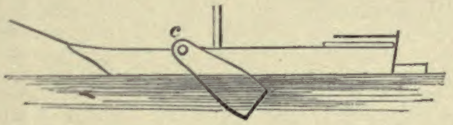
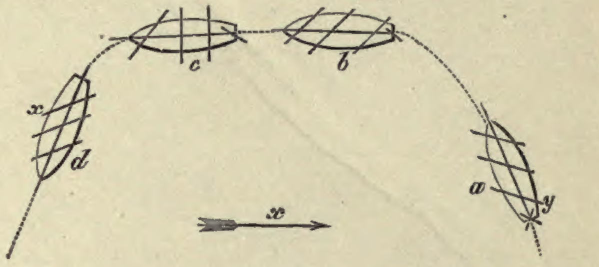
[*] This was first published in 1842. In the spring of 1845, the Nautical Almanac of the year was nearly exhausted, and it was necessary to reprint it with the utmost speed. The Nautical Almanac contains more than 500 large octavo pages of numerical tables. Clowes and Son, all revision being left to their own readers, performed the task in seventeen *working* days, from the commencement of the composition to the delivery in sheets. The accuracy of this reprint was never impeached. A printer who was engaged upon an article in which the above statement was made, assured the author that he must be wrong, that the reprint was made from standing type, as was proved by the revision being intrusted to the printer: on which proper attestations were procured from Clowes and Son and their overseers, and these we have seen. Even printers, when their work is all of the ordinary kind, are not, it should seem, aware of the confidence due to those who are habitually concerned with such things as tables. This reprint, when it came to be examined, had only thirty-three errata. The necessity occurred again in 1846, and, as appears in the advertisement to the second edition of that work, the reprint was fully done in *sixteen* working days. Subsequent revision detected only twenty-two *errata*, seven of which were in *some copies only*, that is, due to hurried press-work. There was then perceptible progress, both in speed and accuracy.

The motion of a ship in thus beating to windward (as the whole evolution is called) is considerably affected by the form of the ship herself; for barges, and flat or round-bottom vessels make great leeway, or are driven bodily from the wind, and the actual course sailed is upon a line which is the resultant of two forces. For supposing the wind to be acting in the direction indicated by the arrow in the diagram, its power upon the mass of broadside and sails will have a tendency to drive it from A towards B (this is called leeway), while the action of the sails in their obliquity to the keel drives the body also forward in the line of keel A C. Now compounding these two forces, A B and C D, we have the parallelogram A D as the resultant, while the amount of leeway would be measured by A B, and its angle would be E A F. Hence tacking is more advantageous to sharp-bottomed vessels with a rising floor like yachts, cutters, &c., as they offer more vertical resistance to the water in arresting the lateral drift A B. Vessels having no keel or deadwood are generally furnished with what is called a "lee-board," which working on a strong pin, as at C in the figure, is let down below the bottom on the lee side to prevent too much leeway when tacking to windward.





In order to very briefly explain the operation of tacking (or as it is also called "heaving about"), suppose the figure below to represent a ship at *a*, beating towards the direction of the wind *x*, and close hauled on the port tack accordingly, the tiller is put over towards *y* ("hard a-lee"), which causes the rudder to bring the ship's head to wind, as at *b*, or throws her into "stays;" just before she reaches this position, the afteryards (on the main and mizen masts) are hauled aback and then braced as at *c*, and as soon as the ship's head is found to be about five points from the wind the head yards are braced round likewise, and the ship fills with the wind upon the starboard side, as seen at *d*, and she is now on the starboard tack. It is at times a perilous evolution, and if there be much sea on is found impracticable. To insure success however under ordinary circumstances, the helmsman just previously keeps the sails "clean full" (as the expression is), lest the ship's velocity be insufficient to bring her head to wind; if it be so, her head "falls off" again, and she is said to have *missed stays;* this is frequently caused by the helmsman neglecting to shift the helm when the ship acquires stern-way. When, from having lost all velocity, she will neither stay nor fall off, she is said to be "jammed up in the wind," or "in irons," the remedy being to brace the head-yards aback and "pay off." If such happen when too near shore the danger is imminent. (VEERING.)



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